CTOBER 1961
LUME 4 • NUMBER 10

- Ksienski — Signal Processing Antennas — Part I
- Dawirs — A Simple Method of Transforming Impedances Through a Lossless Network
- Beust & Ford — Arcing in CW Transmitters
- Feist — Determination of Maximum Insertion Loss Error Due to Mismatch
- Jones — Concerning Hybrids

the microwave journal

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POSITIVE REACTANCE COMPONENT
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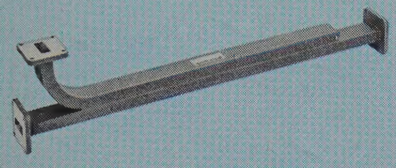
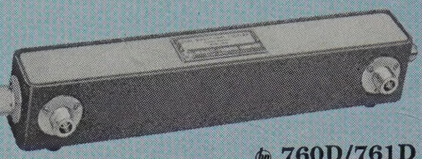
In This Issue . . . **SIGNAL PROCESSING ANTENNAS — PART I**

TESTED *waveguide and coaxial equipment*



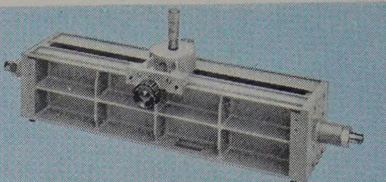
hp 752 Multi-Hole Coupler

Precision directional couplers provide coupling factors of 3, 10 or 20 db. Coupling accuracy ± 0.4 db or 0.7 db. Directivity better than 40 db full range, SWR less than 1:1 (752A), 1:05 (752C/D). Cover frequencies 2.6 to 40 GC. $100.00 to $375.00.



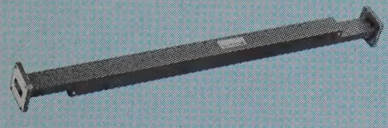
hp 760D/761D Dual Directional Couplers

Ideal for reflectometer systems, these coaxial couplers are flat to ± 0.5 db over 4-to-1 frequency range. Directivity is 35 db (760D) and 30 db (761D). Feature high power capacity, low insertion loss and SWR. hp 760D, 250 MC to 1 GC, $200.00; hp 761D, 1 to 4 GC, $185.00.



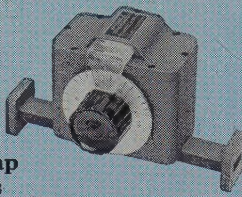
hp 870A/872A Slide Screw Tuners

For waveguide, coaxial (872A shown) applications. Probe position, penetration sets up reflection cancelling existing reflection. Lead screw or micrometer varies probe insertion for 870A Tuners, 2.6 to 40 GC, $125.00 to $300.00. Micrometer drive varies insertion on 872A, 500 MC to 4 GC, $525.00.



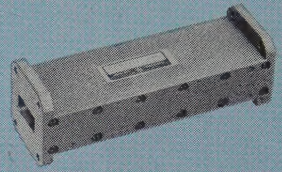
hp 372 Precision Attenuators

Rugged, broadband fixed attenuators retaining precise calibration regardless of humidity, temperature or time. Invariant attenuation assured by permanent, "multi-hole coupler" joining of two waveguides. 10 and 20 db models, 2.6 to 18.0 GC. $110.00 to $400.00.



hp 375A Variable Flap Attenuators

Simple, convenient for adjusting waveguide power or isolating source and load. Max. SWR less than 1.15 full range; attenuation variable 0 to 20 db, dissipates average powers up to 0.5 or 1 watt. S through R bands, 2.6 to 40.0 GC. $90.00 to $190.00.

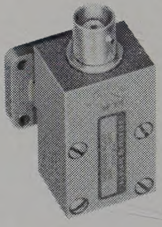


hp 362A Low Pass Filter

Compact models increase SWR measurement accuracy by suppressing harmonics; feature low insertion loss, broad stop band. 8.2 to 40.0 GC (includes N-band model). $325.00 to $385.00.

hp 430C Microwave Power Meter
hp 476A/477B/485 Mounts

hp 430C reads rf power direct in dbm or mw, requires no calculations. Covers 2.6 to 40.0 GC, operates with hp 476A, 477B, 485 bolometer, thermistor or detector mounts; also with hp 487 Broadband Waveguide Thermistor Mounts (see alongside). hp 430C, (cabinet), $250.00; hp 430CR, (rack mount), $255.00. hp *476A Universal Bolometer Mount,* 10 to 1,000 MC without tuning, $85.00. hp *477B Coaxial Thermistor Mount,* 10 MC to 10 GC without tuning, $75.00. hp *485 Detector Mounts* available in three basic series: S485A 2.60 to 3.95 GC, no tuning; 485B, 3.95 to 12.4 GC; 485D, 2.6 to 8.2 GC. 485 models, $75.00 to $185.00.



hp 487 Waveguide Thermistor Mounts

Models covering 2.6 to 40.0 GC. Each covers full range of guide; no tuning, SWR 1.35 to 2.0. 10 mw max power. Uses permanently installed 100 ohm negative coefficient thermistor; 18.0 to 40 GC models use 200 ohm thermistor. $75.00 to $225.00.

hp 810/815B Slotted Sections

hp 810B Slotted Sections. hp 810B, for 809B carriage, flanged, waveguide section with accurately machined slot. Slot tapered at ends to minimize reflection. 3.95 to 18.0 GC. $90.00 to $125.00.

hp S810A. Complete slotted section assembly including probe carriage. In 2.6 to 3.95 GC (S-band) size only. $450.00.

hp 815B Slotted Sections. For mounting in 814B carriage. Available in two bands, 18.0 to 40.0 GC. Accurately machined; easy interchange, precise positioning. $265.00.

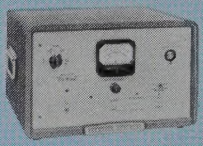
hp 806B Coaxial Slotted Section. 3 - 12 GC, fits 809B, Type N connectors. $200.00.

hp 805C/D Slotted Lines

Utmost mechanical rigidity, less leakage, greater accuracy, SWR 1.02 or 1.04. Range 500 MC to 4 GC, reads in cm and mm to 0.1 mm. hp 805C, for 50 ohm Type N, hp 805B, for 46.3 ohm RG 44/U. hp 805C, $525.00; 805D, $600.00.

hp 415B/C Standing Wave Indicators

hp 415B operates with all hp waveguide and coaxial slotted sections, gives readings in SWR or db. Low noise level, 0.1 μv full scale sensitivity, 60 db calib. attenuator. $200.00 (cabinet), $205.00 (rack). *New* hp *415C* (pictured) offers similar characteristics but is transistorized, incorporates revolutionary four-times expansion of readings at any point on any scale. Price on request.



hp 416A Ratio Meter

Displays ratio between two signals, irrespective of common amplitude variations. Especially useful for swept frequency measurement of VSWR, reflection coefficient, gain, insertion loss and other microwave parameters. Calibrated in VSWR, % reflection, db. See offer for hp Application Note 42 elsewhere in this advertisement. $550.00 (cabinet), $535.00 (rack).

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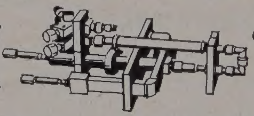
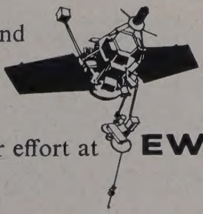
celestial bodies — In the extensive programs of unmanned space exploration — lunar, planetary and interplanetary — vast amounts of scientific knowledge will be gathered concerning the planets and stars and their environments. These programs rely on satellites with payloads of extremely precise research instruments and systems — delicate beyond description yet rugged enough to withstand the severities of rocket launch and space travel.



Ewen Knight's intense research and development efforts have resulted in scientific systems (space borne and land based) which probe for the unknowns in space. Because of these unique projects, advanced radiometry navigation, radar, telemetry, communications and related devices, up to millimeter wavelengths, are areas in which Ewen Knight is recognized for its leadership.



Research and instrumentation programs for space exploration will continue to search beyond unknown horizons. This work will continue as a major effort at **EWEN KNIGHT CORPORATION**
East Natick, Massachusetts

OCTOBER, '61 vol. 4 - no.10

the microwave journal

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Frequency Control By Microwave Atomic Resonance

Ferrimagnetic Limiters

RF Leakage Characteristics of Popular Coaxial Cables and Connectors, 500 Mc to 7.5 Gc

Signal Processing Antennas — Part II

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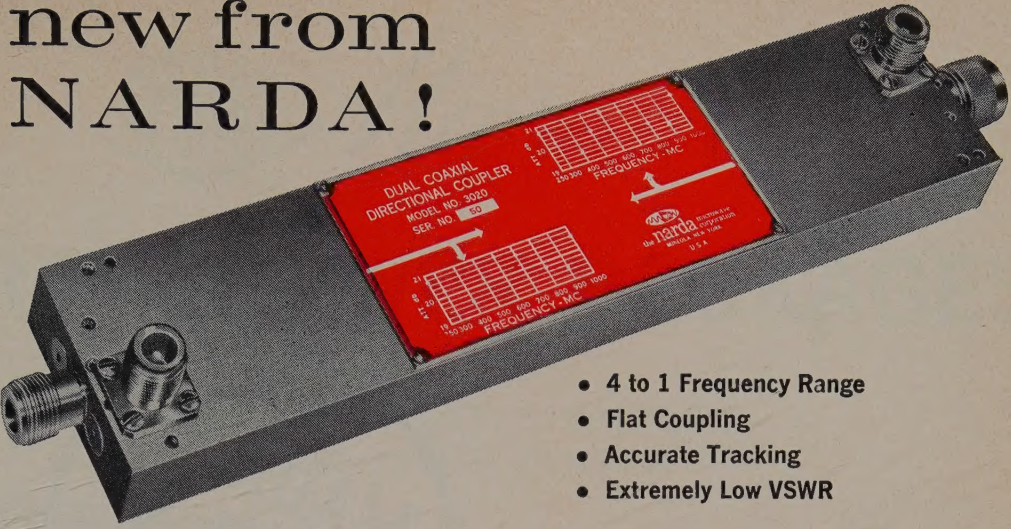
BPA

new from NARDA!



- **4 to 1 Frequency Range**
- **Flat Coupling**
- **Accurate Tracking**
- **Extremely Low VSWR**

high-directivity coax couplers

Specifically designed for REFLECTOMETER applications!

- Here are two brand new coax couplers, specifically designed by Narda to provide the extremely high directivity needed in Reflectometer setups. And when we say "extremely high directivity", we mean it! For example: Model 3020 (250 to 1000 mc) has a directivity of 35 db minimum, which means a maximum error in VSWR of only 1.035 can occur as a result of the finite directivity. Main line VSWR is held to 1.05 maximum; secondary line VSWR is 1.10 maximum!

- What's more, each model covers two full octaves; each features extremely accurate tracking (0.3 db maximum change in difference between forward and reverse coupling over the band); each has a power rating of 100 watts CW, 10 kw peak. Check the table for full specifications—and compare with any other units available.

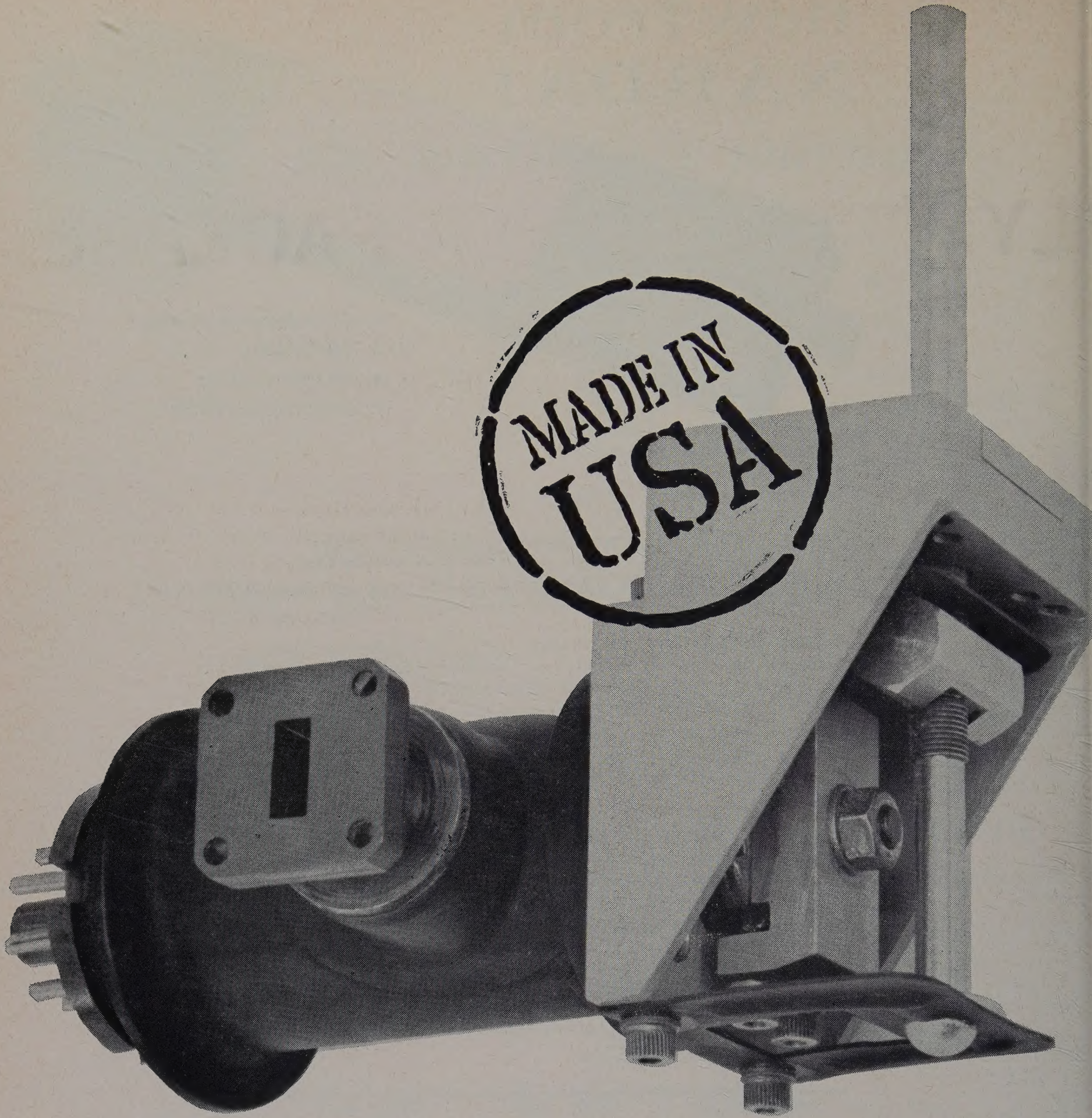
- These are just two examples of the complete line of unusually fine microwave and UHF instrumentation available from Narda. Write today for your free copy of our newest catalog. Address: Dept. MJ-61-4.

SPECIFICATIONS	MODEL 3020	MODEL 3022
Frequency	250 to 1000 mc	1000 to 4000 mc
Directivity	35db min	30db min
Coupling—both arms	20db nominal	20db nominal
—Frequency sensitivity	±0.6db approx.	±0.6db approx.
Max VSWR—main line	1.05	1.10
Max VSWR—secondary lines	1.10	1.15
Power Rating	100W cw 10kw peak	100W cw 10kw peak
Tracking	0.3db total	0.3db total
Price	$200.	$185.

the **narda** microwave corporation

PLAINVIEW, LONG ISLAND, N. Y.

GE 3-9000



Tube Type 9521 35-40 kmc. 60 mw typical power output.

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The same quality EMI Reflex Klystrons known throughout the world—now manufactured and marketed by EMI/US right here in America. EMI/US, the new American member of worldwide EMI, now offers a broad line of Reflex Klystrons with the following characteristics:

INTEGRAL CAVITY TUBES: Long life at millimeter frequencies. High power output at millimeter frequencies. Range: 12-40 kmc.

EXTERNAL CAVITY TUBES (Plug-in Type): Each individual tube has wide frequency range capability. Tubes in range of 1-12 kmc.

Other EMI electron tubes now available from EMI/US include: Photomultipliers, TWT, Cathode Ray Tubes, TV Camera Tubes, Magnetrons and Microwave Equipment.

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FOR THEIR POWER

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62A1—UNIVERSAL KLYSTRON POWER SUPPLY

Most versatile klystron power unit available today. Widest beam power range (delivers —200 to —4000 volts from 0 to 150ma) in the smallest and lightest package on the market.

62A2—KLYSTRON FILAMENT SUPPLY

Regulated source of filament power for the most critical measurements. With insulation for beam supplies up to 4000 volts, 62A2 can deliver up to 2 amps. with voltages from 2.5 to 10 volts, continuously adjustable. Close regulation; low ripple.

62A3—KLYSTRON POWER SUPPLY

Ideal for average lab uses—at a moderate price. Supplies most types of klystrons with beam voltages from —200 to —700 volts, using up to 70ma. Weight only 32 lbs.

● For further details and information as to laboratory applications of these power-packed units, please write us:

SPERRY

	62A1	62A3
BEAM	—200—4000 v., continuously adjustable. 0 to 150 ma., 1 v. line regulation, 3 mv. max. ripple.	—200 to —700 v., continuously adjustable. 0 to 70 ma., 1 v. line regulation, 5 mv. max. ripple.
REFLECTOR	0 to —1000 v., .01% regulation; 3 mv. max. ripple.	0 to —1000 v., 0.1% regulation, 5 mv. max. ripple.
FILAMENT	6.3 v., 4 amps., with provision for external filament supply.	6.3 v., 0 to 2 amps.
MODULATION	0 to 250 v., peak to peak, all waveforms.	0 to 150 v., peak to peak, all waveforms.

	62A2
VOLTAGE	2.5 to 10 v. d.c., continously adjustable
CURRENT	2 amps. max.
RIPPLE	5 mv. max.

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MICROVIEWS
OF THE MONTH

77 ▶

SIGNAL PROCESSING ANTENNAS — Part I

A. Ksienski

Various types of signal processing antennas are described and analyzed. It is shown that antennas are needed which can significantly exceed the performance of the conventional array in certain respects. The signal processing antennas are shown to achieve these objectives, but at the expense of certain other characteristics which are degraded. The trade offs involved in the different types of processing antennas are described and the reasons for their occurrence explained. The techniques presented include, switching antennas, non-linear processing antennas, time varying antennas and wide band antenna systems.

86 ▶

A SIMPLE METHOD OF TRANSFORMING IMPEDANCES THROUGH A LOSSLESS NETWORK

Harvel N. Dawirs

This paper describes a simple method of transforming admittances through any lossless, four-terminal network. The transformation results from the choice of input terminals as the point in the input transmission line at which a null occurs when the output terminals are short circuited. With this choice the input admittance Y_i *is related to output admittance* Y_o *by the linear equation* $Y_i = K_oY_o + jB_{oc}$ *where* K_o *and* B_{oc} *are easily determined, real constants. Thus the admittance transformation consists of the simplest of arithmetical operations, multiplication by a real number and the addition of an imaginary component, regardless of the complexity of the network. The method is also capable of considerable precision with a little care in the determination of the constants* K_o *and* B_{oc}*.*

91 ▶

ARCING IN CW TRANSMITTERS

Walter Beust and Willard L. Ford

The operation of high average power CW radars has produced waveguide arcing at powers several orders of magnitude below that expected from dielectric rupture. An engineering evaluation aimed at eliminating or controlling the destructive effects of arcing is described, and the resulting observations and recommendations are presented.

98 ▶

CONCERNING HYBRIDS

C. W. Jones

In all but the simplest of RF circuits the class of circuit elements known as hybrids plays a vital role. They have for over two decades made possible the large number of balanced circuit configurations found in modern RF systems, among which are single sideband modulators, balanced mixers, constant impedance filters, linear phase shifters, balanced duplexers, and monopulse comparators to name a few. In the future, as the complexity of RF systems increases, the hybrid circuit will undoubtedly play an ever increasingly important role.

OUR COVER

Shown is a data processing system for obtaining simultaneously scanned antenna patterns developed at Hughes Aircraft Company. The receiving antenna consists of a five-element slot array. The elements are switched on and off sequentially by microwave diodes controlled by the electronic programmer to the right of the array. The receiver processes the resultant phase modulated signal and resolves it into frequency components. Each component corresponds to a beam pointing in a different direction. The recorder illustrates the experimental patterns, each corresponding to a different frequency component. See page 77.

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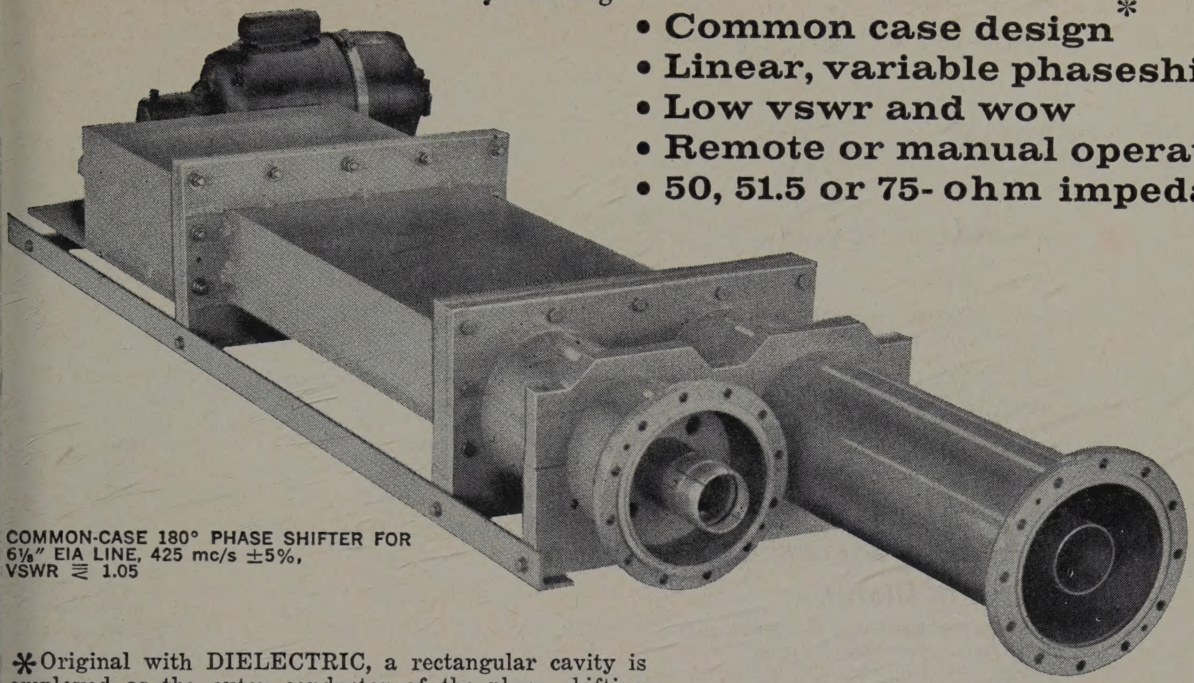
microwave
journal
In This Issue   SIGNAL PROCESSING ANTENNAS — PART I

from Dielectric

High Power Phase Shifters

featuring

- **Common case design***
- **Linear, variable phaseshift**
- **Low vswr and wow**
- **Remote or manual operation**
- **50, 51.5 or 75-ohm impedance**



COMMON-CASE 180° PHASE SHIFTER FOR 6⅛" EIA LINE, 425 mc/s ±5%, VSWR ≦ 1.05

*Original with DIELECTRIC, a rectangular cavity is employed as the outer conductor of the phase shifting coaxial assembly. Sliding joints are thereby eliminated on the outer conductor, greatly reducing the conductor alignment problem. Longer life, increased power handling capacity, freedom from wow, and economy are the result.

In gaining these several advantages, common-case phase shifters do become limited in band width by the VSWR specification. Their usual application is in systems where the operating frequency is within a 20% band, ±10% about a specified center frequency. But for every application within this one limitation, common-case phase shifters will satisfy every performance need.

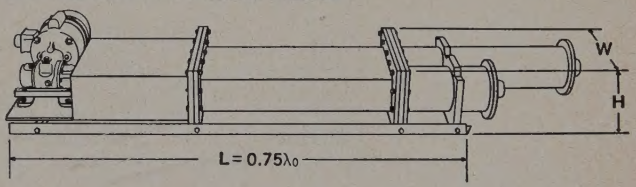
The phase shift is very linear because of the simplified mechanical structure, and is continuously variable. Both manually and electrically controlled models are available.

In the latter case, adjustable electrical limit stops as well as positive mechanical stops are provided. For remote, electrical operation, a precision potentiometer is connected directly to the travel mechanism for accurate position information. These units can be furnished in any line size from ⅞" OD and up; 50-, 51.5-, or 75-ohm impedance; with either EIA (RETMA) or QUICK-CLAMP flanges, or without flanges.

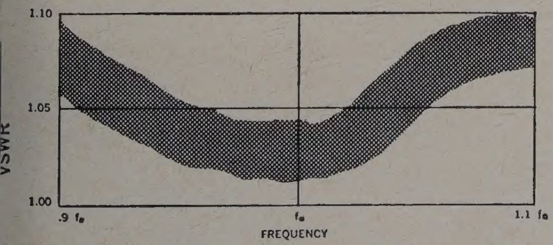
Power handling capacity, upper frequency limits, and approximate physical dimensions are shown in the accompanying table and outline drawing. Also illustrated is typical graph of VSWR vs Operating Frequency. The vertical dimension of the grey band is the VSWR variation over 180° of phase shift.

To order, specify frequency range, line size, line impedance, flange type, phase shift/minute if motorized, and position-indicator details. For further information including price, contact our Proposal Engineering Department.

OUTLINE DRAWING — 12000 SERIES



TYPICAL VSWR vs OPERATING FREQUENCY
(Vertical height of band is variation over 180° of phase shift)



CONDENSED SPECIFICATIONS — 12000 SERIES

LINE SIZE (in.)	POWER (kw, max)	UPPER FREQUENCY LIMIT	APPROXIMATE DIMENSIONS (inches)		
			W	H	L
⅞	12 @ 1, 4 @ 100, 1 @ 1000 mc/s	3600	5	4	$0.75\lambda_0$
1⅝	15 @ 100, 4.5 @ 1000, 2.4 @ 3000 mc/s	3200	6	4	
3⅛	150 @ 10, 48 @ 1000 mc/s	1000	10	5	
6⅛	600 @ 10, 190 @ 100 mc/s	500	14	7	
9³⁄₁₆	1400 @ 10, 380 @ 100 mc/s	350	24	12	$0.75\lambda_0$

DIELECTRIC'S areas of capability include coaxial, waveguide and open wire techniques . . .

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HANDBOOK

More than a year ago we announced the creation of the *Microwave Engineers' Handbook and Buyers' Guide.* Since the first announcement, we have been busy collecting, selecting and editing material.

Many of you have responded to our request for information and material. Some of the material we will use, but unfortunately more of it we will not be able to use. The response from our audience was a pleasant experience. We have carefully adhered to our policy of "first come first served." In addition, we have been careful to limit the contents to material acceptable by the Handbook editors.

The contents of the Handbook will include a manufacturers directory, a product directory, the technical section, and, of course, the section that makes it all possible — the advertisers section.

I would especially like to mention a few of the facts relating to the technical section. At this time we have approximately 190 pages of text. It is made up for the most part of design graphs. In addition, there are a large number of nomographs, tables, and charts.

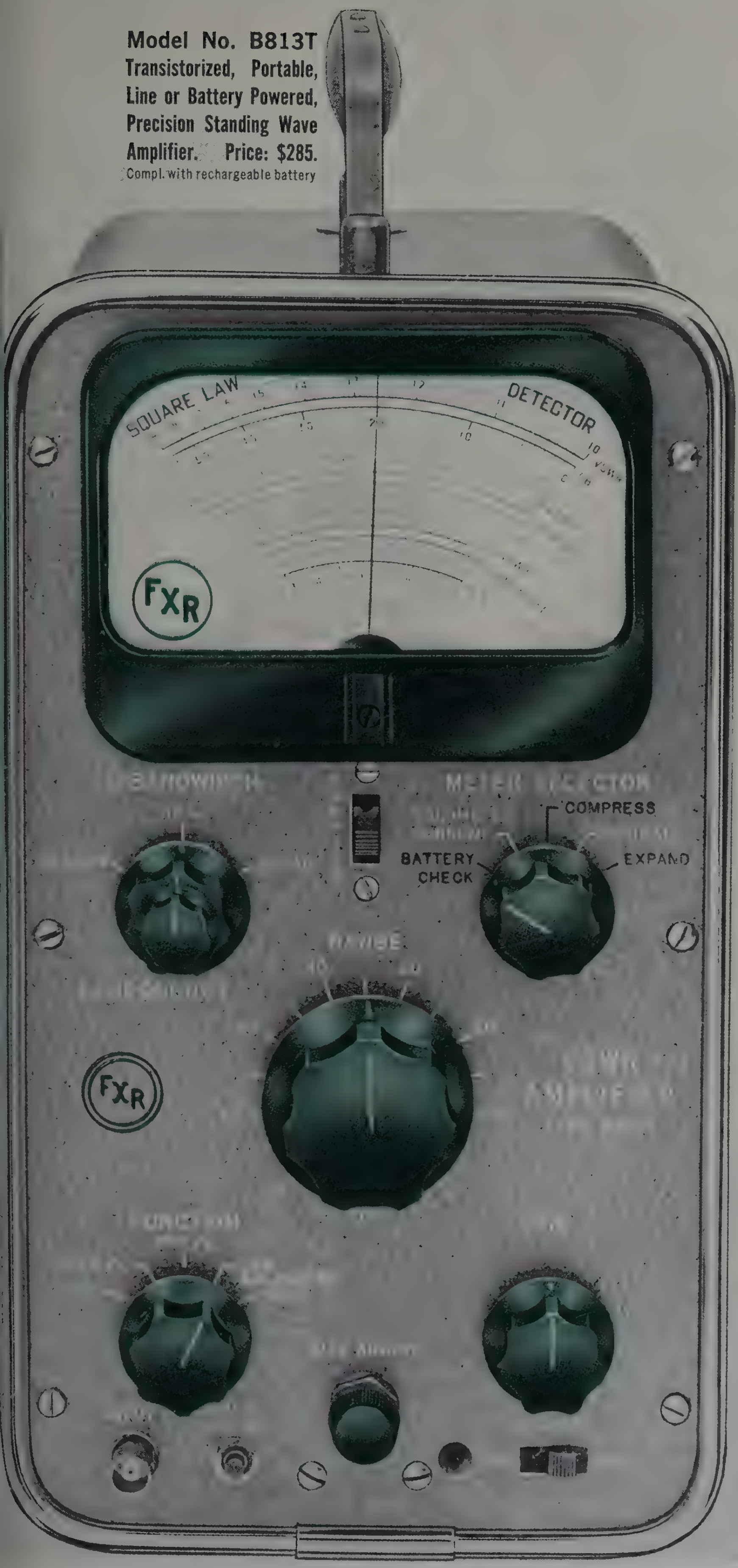
With the exception of the tables, some of which occupy several successive pages, each page is complete unto itself. In other words, where an explanatory text is required, it will appear on the same page as the graph or nomograph.

There are sections devoted to Transmission Line Theory, Waveguides, Coaxial Lines, TEM Lines, Antennas, Directional Couplers, etc. We do not pretend that the Handbook is a complete and final collection of the best information in Microwave Design. We do state, however, that it is a step in that direction.

Since the Handbook is an annual publication, we plan to revise it and add to it each year. We will be looking for your comments, criticisms, and useful information to help guide us in the future. Many people have devoted long hours to make the Handbook possible. We are confident that you will not be disappointed.

One final word of caution. To receive the Handbook, you must be a subscriber of "the microwave journal" — we advise you to check. If your subscription is in order, there is only one more thing to say — clear off a space on your desk, the Handbook is coming soon.

Ted Saad



Model No. B813T
Transistorized, Portable, Line or Battery Powered, Precision Standing Wave Amplifier. Price: $285.
Compl. with rechargeable battery

the new FXR transistorized precision standing wave amplifier has exceptional accuracy of ±0.05 db

This ±0.05 db accuracy, the most precise in the industry, holds true for both the full scale meter movement and for each 5 db step on the range switch. The specially designed meter and linear amplifier give a full scale maximum error at 5 db of only ±0.05 db. This marks a significant increase in accuracy over any existing Standing Wave Amplifier. Calibrated range of the B813T is 75 db.

While extreme measurement accuracy was the major design criterion for this transistorized, portable instrument, many other design features are worthy of note: special circuitry and controls for normal, expanded and compressed scale readings (gain normalized on switching) . . . bolometer resistance checking, protection and current adjustment . . . selective meter damping . . . bandwidth selection and frequency peaking . . . range selection in 5 db steps . . . battery voltage checking and self-contained battery charging.

Write or call for Bulletin B813T for details on the most accurate Standing Wave Amplifier available for microwave measurements.

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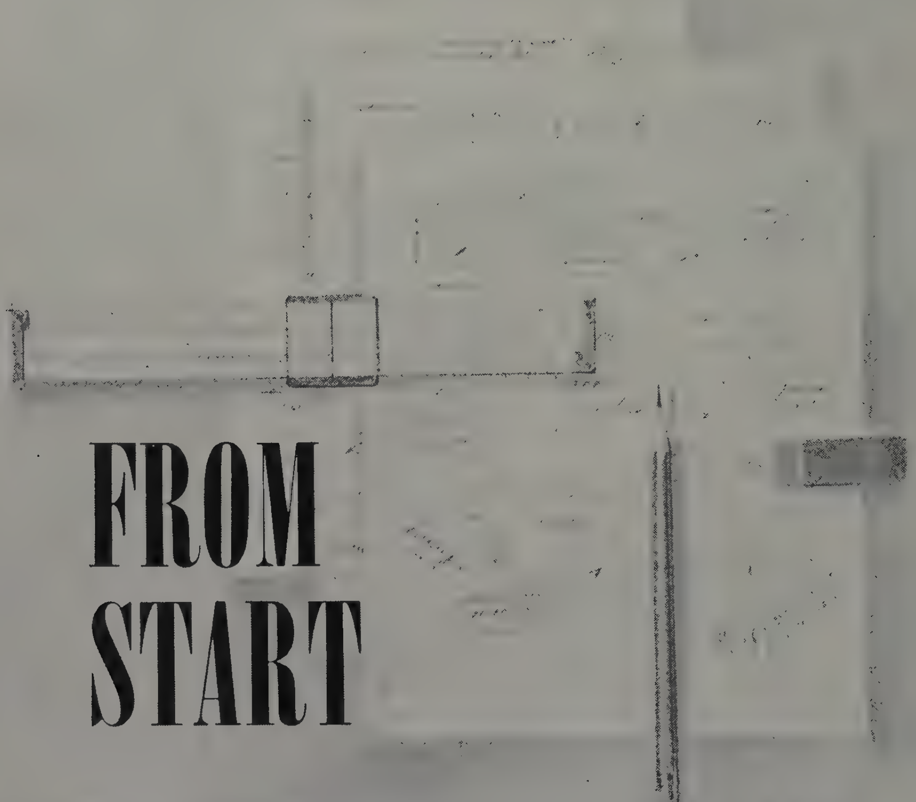
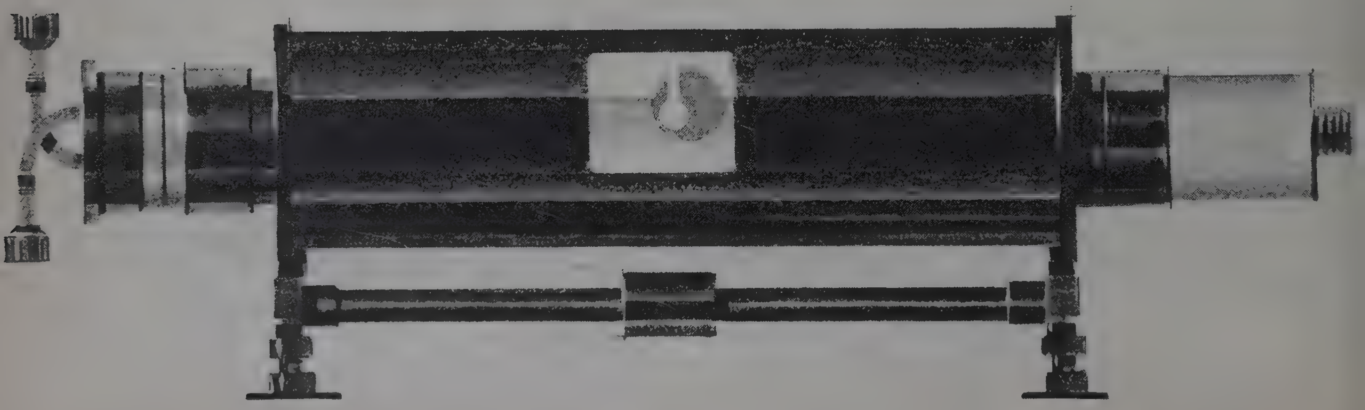


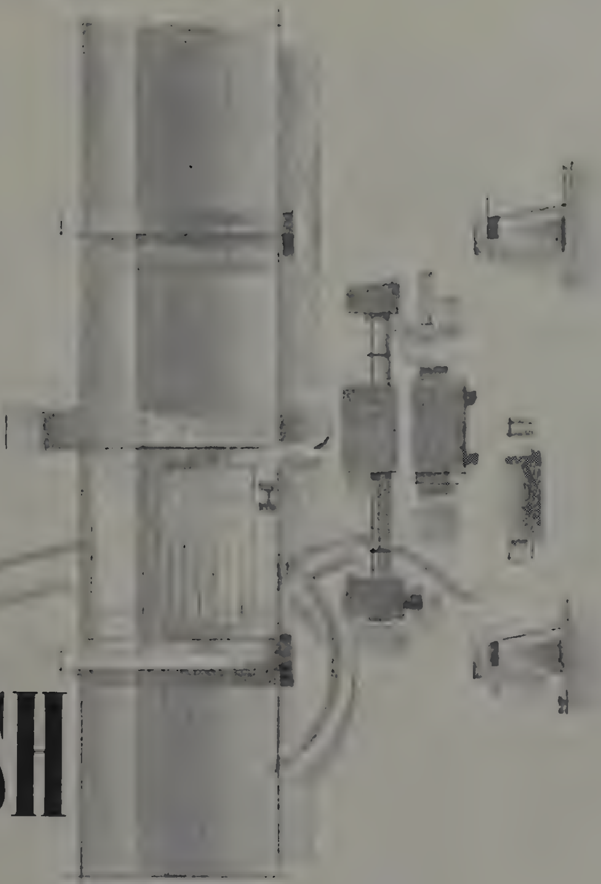
FROM START

1 TECHNICAL SERVICE Some tubes fit—some don't. Your system may have a socket that will take an off-the-shelf item—or it may require a small modification to an existing tube, or even a totally new design. Whether you want to start from scratch, or prefer a catalogue item, Hughes liaison engineers and the entire Division will provide just the service needed.

2 RESEARCH & DEVELOPMEN Hughes, an acknowledged leader in mic wave tube research and development, continuing the necessary gun, circuit, a materials processing research and developmen provide the most advanced traveling-wave am fiers and backward-wave oscillators for the n generation of ECM, radar, and communicati systems. These advanced programs are suppor by a variety of prime contractors and milit agencies as well as company funds.



TRAVELING WAVE TUBE PROBLEMS



TO FINISH

PRODUCTION Hughes is now delivering traveling-wave tubes at annual rates that number in the thousands. This outstanding growth results from an ability to transform sophisticated development tubes into production versions rapidly and economically. It also includes the ability to deliver one off-the-shelf item or an entire communications or weapons system tube requirement, umbering in the hundreds, with equal dispatch and reliability of product.

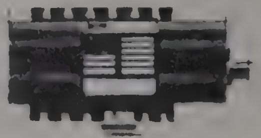
307H 8.5—9.5 kMc; 50 KW Min P_o; 500 W Ave P_o; 54 db Gain; PPM Focused

311H 2.0—4.0 kMc; 1 KW Min P_o; 10 W Ave P_o; 36 db Gain; Gridded, PPM Focused

310H 8.5—10.5 kMc; 1 KW Min P_o, 20 W Ave P_o; 40db Gain; PPM Focused

308H 8.6—9.8 kMc; 15 KW Min P_o; 150 W Ave P_o; 53 db Gain Gridded, PPM Focused

346H 7.0—12.4 kMc; 30 mw P_o; PM Focused BWO.



316H 12.4—18.0 kMc; 10—65 mw P_o; PM Focused BWO.

or more information about the production TWT's shown above, other Hughes tubes, contact your nearest district office.

RTHEASTERN 4 Federal Street, Woburn, Mass. WEllis 3-4824 **EASTERN** 2000 "K" Street,
V., Washington 6, D. C. FEderal 7-6760; 13 Lloyd Avenue, West Long Branch, N. J., CApital 2-1111
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MICROWAVE TUBE DIVISION

Circle Reader Service Card 6

Industry News

SYLVANIA APPOINTS DONNER MANAGER OF MICROWAVE AND ANTENNA LABORATORY

The appointment of John B. Donner as manager of the microwave and antenna laboratory at the Waltham Laboratories of Sylvania Electric Products Inc., has been announced by Richard M. Osgood, general manager of the Waltham Laboratories.

Mr. Donner joined Sylvania in 1953 as a senior engineer in the company's Boston Engineering Laboratory. He subsequently directed several large electronic countermeasures engineering programs for Sylvania, including that for th B-58 "Hustler" bomber. In March, 1961, Mr. Donner was appointed manager of the advanced development laboratory, a position which he will continue to hold jointly with his new responsibilities.

The microwave and antenna laboratory of the Waltham Laboratories is responsible for the development of new techniques for the design of antenna and microwave components, as well as engineering design for a wide variety of ground-based, airborne and missile antennas and related devices. Among those presently under development are the antennas for the U.S. Army Signal Corps' ADVENT communications satellite ground terminal stations.

Mr. Donner received a bachelor's degree in electrical engineering from Massachusetts Institute of Technology in 1949. Following graduation from M.I.T., he taught television theory and servicing at Saunders' Radio and Electrical School in Boston. In 1951, he joined the staff of General Electronics Laboratories in Boston, where he designed various devices used by the Navy.

Mr. Donner is a member of the Institute of Radio Engineers, the IRE's Professional Group on Military Electronics, and the National Security Industrial Association.

— *m w j* —

POLARAD AWARDED $1 MILLION AIR FORCE CONTRACT

An Air Force contract for radar plan position indicators has been awarded Polarad Electronics Corp., Long Island City, N.Y.

Intended for use as part of air traffic control systems, these units will be used to display radar information to enable an operator to detect, direct, and control aircraft from a ground station.

The value of the contract is in excess of a million dollars.

— *m w j* —

L. B. YOUNG HEADS BENDIX SYSTEMS DIVISION

The appointment of Louis B. Young as general manager of the Bendix Systems division, Ann Arbor, Mich., has been announced by Dr. R. D. O'Neal, vice president of engineering for the Bendix Corporation. He succeeds Roy J. Sandstrom, who recently was promoted to the Bendix Mishawaka division, Mishawaka, Ind.

Young has been with the Systems division since it was organized almost five years ago. He graduated from Marietta (O.) College in 1941 and received his MS degree in physics from the University of Illinois in 1942. He then joined Radiation Laboratory of the Massachusetts Institute of Technology where he was a section head, helped to establish the MIT Radar School, and was an author for the Radiation Laboratory series of books on radar.

Young joined the Systems Planning Group of Bendix in 1955, and with the formation of the Bendix Systems division, headed the Long Range Planning Department. He was appointed assistant general manager in January, 1960.

— *m w j* —

(Continued on page 16)

MEC Reports

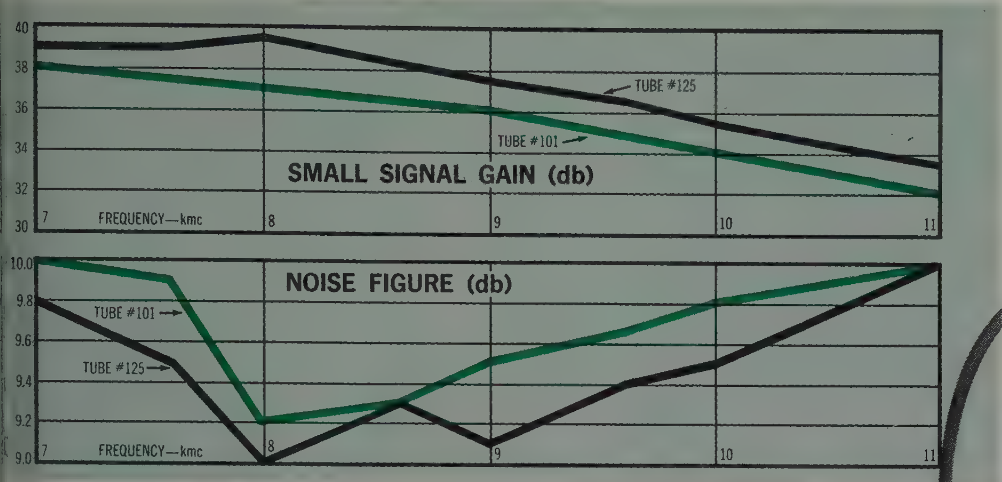
S, C and X-Band,
Metal-Ceramic, PPM Focused,
Magnetically Shielded,
10 mw Output and 30 db Gain
with Maximum Broadband
Noise Figure of 10 db.

Typical of MEC's advanced family of metal ceramic low noise traveling-wave tubes is the new M2105. Rugged and reliable, this tube is the result of engineering skill and manufacturing care appropriately combined to form a production tube with truly reproducible characteristics.

Shielding of the tube and its focusing structure, an advantage of the PPM format, eliminates the effect of stray magnetic fields and permits use of tubes in close proximity to magnetic materials or to each other. Elimination of the focusing solenoid and power supply reduces power consumption to less than 3 watts, including heaters, and does away with auxiliary cooling.

Ask for your copy of our new cata

ow Noise TWT's with PPM Focusing



REPEATABILITY MEANS RELIABILITY. Notice how closely the small signal gain and noise figure characteristics for the first M2105 (#101) compare with those of the last member in the first lot (#125).

Model M2105 Low Noise TWT weighs 5 pounds and is 12⅝" long.

ility—
-in Feature of MEC Tubes

l-ceramic construction gives
tubes a headstart on reliability.
are evacuated at higher temper-
(650°C), producing a higher
m and cleaner environment for
athode life.

ently rugged, they provide supe-
erformance over environmental
mes. (The M2105 withstands
hock and 15 g vibration between
2000 cycles with no degradation
formance. Temperature compen-
work is now being completed.)

construction features also in-
a stacked ceramic gun and a
rigidly supported by three
ic rods. Critical turn spacing is
ately maintained to assure uni-
gain characteristics from tube-
e. The tube can be operated in
osition without change in char-
stics.

MEC's new short form catalog with complete information on our production engineered line of traveling-wave tubes is available now. In addition to low noise types, the catalog covers medium and low power, serrodyne, and special purpose tubes. For your free copy, call your nearest MEC engineering representative or write to us.

TYPICAL LOW NOISE TWT TUBES IN PRODUCTION

PPM FOCUSED TUBES	Frequency Range	Small Signal Gain	Saturation Power	Noise Figure
M2103 Series (Family)	2 - 4 kmc	30 db	10 mw	10 db
	(over 0.5 kmc portion of the band)	30	10	8
	2.3 - 4.4	30	10	10
	2 - 4	30	10	15
M2112 Series	4 - 8	30	10	10
	4.3 - 7.4	30	10	10
	4 - 8	30	10	15
M2105 Series	7 - 11	30	10	10
	7 - 11	30	10	15
	8 - 12.4	30	10	15
M2114	12.4 - 18	30	5	14
SOLENOID FOCUSED TUBES				
M2103 Series	2.0 - 4.0 kmc	30 db	5 mw	8 db
	(over 0.5 kmc portion of the band)	30	5	6
M2107	4.0 - 8.0	30	5	10
M2101 Series	7.0 - 11.0	30	10	9
M2114	12.4 - 18.0	30	5	12

MEC

MICROWAVE
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Palo Alto, California
DAvenport 1-1770

Circle Reader Service Card 7

Is it a relay or coaxial switch?

Some people call this electro-magnetically actuated device a relay. We call it a coaxial switch. Do you know what the difference is?

First, the conventional relay, even when shielded and coaxially terminated isn't suited for use in circuits above 400 mc. In fact, even at this relatively low frequency, such a relay may have a VSWR of 1.5. The DK Coaxial Switch with improved impedance match will show a VSWR of only 1.1 at the same frequency.

Standard DK Coaxial Switches are designed for frequencies up to 5,000 mc. Models under development will soon extend this to the 10,000 mc range.

Improved VSWR is only one difference. DK Coaxial Switches offer *lower crosstalk, reduced insertion losses,* and great *environmental reliability.*

RF Products can supply over 1300 individual switch designs. But, since 132 of these meet 90 per cent of known applications, we have prepared a simplified catalog which makes it easy for you to find the switch you need. Write for Catalog DK61.

If you don't find the switch you want in this catalog, your local RF Products representative can supply you with information on hundreds of existing alternatives, or help you to design a new switch to solve your specific problem.

RF PRODUCTS

Division of Amphenol-Borg Electronics Corp., 33 East Franklin St., Danbury, Conn.

ipc DK AMPHENOL

THE ANSWER . . . IS A CONSCIENTIOUS PROGRAM
F CRYOGENIC ENGINEERING AND DEVELOPMENT
N A BROAD FRONT."

LOW TEMPERATURE ELECTRONICS

BENJAMIN LAX,* ASSOCIATE EDITOR, *the microwave journal*

Low temperature electronics has invaded the research boratories of the modern world, but as yet it has not ceived a wide acceptance by engineers as the wave of e future. On the contrary, the remarkable achievements presented by the development of the maser, the cryo- on, low temperature semiconducting devices and the perconducting magnet have been viewed by many as ssing fancies which may become ultimately obsolete. is attitude is somewhat surprising since the last few ars have witnessed a major revolution in cryogenic en- neering in connection with our national space program d some of our nuclear research. Formidable problems ve been solved to enable technicians to transport and ndle large quantities of liquid oxygen and liquid hy- ogen. From the standpoint of safety the electronic de- ces utilizing low temperatures are much simpler since ey can be operated with liquid nitrogen or liquid helium.

The story of the maser illustrates the theme of this edi- rial quite appropriately. Shortly after the maser was vented and its low noise capabilities experimentally monstrated, the invention of the ferromagnetic ampli- r and the semiconducting parametric amplifier followed. any practical people hailed these as solutions and pro- eded to climb on the bandwagon of parametric devices d its various forms which even involved electron beams a magnetic field. The ferromagnetic amplifier received good deal of attention with the well defined objective d hope that it would have all the virtues of the maser t would operate at room temperature. This did not aterialize since it proved to be very noisy, although the vice did operate efficiently on a continuous basis. The rametric amplifiers fared somewhat better but did not hieve as low noise figure or stability at the higher mi- owave frequencies as the maser. The moral of the story that the bird in the hand was neglected. The develop- ent aspects of the maser, particularly insofar as the cryo- nic engineering is concerned, have not been pushed gorously enough. This device with all its inherent advantages, can become a more practical and reliable component which will make important contributions to radar, communications and radio astronomy from about 1000 Mc well into the millimeter region.

Advances in low temperature technology will stimulate and encourage other research and development in cryogenic devices. The cryotron has progressed sufficiently in the laboratory that its performance as a computer element is competitive with such devices as the magnetic thin film and in some respects may offer unique advantages. The drawback of course is the necessity of having large number of input and output leads to the cryotron elements. However, if low temperature diodes and transistors were developed, then the entire computer could be immersed in a simple cryostat except for a few simple terminal input and output leads. Such a system would have several possible advantages, among which would be the increased speed of computers which are determined by the speed of present-day transistors and diodes. However, it is well known that conduction and transport of electrons and holes in semiconducting devices are greatly enhanced at low temperatures. From theoretical considerations it is also known that semiconductors with small energy gaps exhibit high mobilities because the effective mass as measured experimentally by cyclotron resonance is extremely small, and therefore the electron is highly mobile. In addition, these materials behave as semiconductors only at low temperatures. Consequently, with the appropriate impurity concentration the mobility of the electron is also larger because the scattering or collision with the lattice is correspondingly reduced. The significance of these two by-products of low temperature operation would be devices whose frequency response could be one to two orders of magnitude higher than that of similar or analogous devices operating at room temperature. This approach therefore could provide a possible solution for high speed computers.

In principle, low temperature, low gap materials open up the possibility of improving conventional semiconducting devices and developing new ones. These would operate at microwave and millimeter frequencies which until now have been restricted to the UHF region of the spectrum. Another class of devices that appears feasible

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Head, Solid State Division, Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology with the joint support of the U.S. Army, Navy and Air Force.

and involves low temperature electronics is that of detectors using solid state phenomena in superconductors and semiconductors. A photoconducting device sensitive in the millimeter and submillimeter region using InSb in the magnetic field has already been developed. Another using the tunneling and superconductors across an insulating film has already been proposed. A third involving cyclotron resonance in semiconductors would offer a tunable detector from the microwave region well into the infrared. Finally, the development of superconducting magnets, which promise to achieve fields of the order of 100,000 gauss in relatively small dimensions, opens up a wide variety of applications which can take advantage of these high fields. Nevertheless, these devices are still the province of experimental physicists who are accustomed to working with low temperature techniques involving relatively crude systems which require transfer of liquid gases from large storage dewars to smaller operating dewars. However, if a well engineered closed-cycle system could be provided, not only would it accelerate an increase in the present research work, but it would encourage many of the development people to work with these devices and thereby place the whole technology on a more practical and therefore useful status. Essentially, until this is don
low temperature electronics will be a bootstrap operatio
which will not mature at the desired rate. Furthermor
instead of working with the system, the engineers wi
continue fighting it.

The answer to this dilemma is a conscientious progra
of cryogenic engineering and development on
broad front. The initial investment and effort on a prop
scale, perhaps at the moment, is too formidable a task f
any individual commercial organization. However, it is
legitimate program on a large scale for such governme
laboratories as the National Bureau of Standards in Bou
der, Colorado, supplemented by coordinated industrial a
tivity sponsored by the Department of Defense and ind
pendent support as well. Once the basic components suc
as compact closed helium, cryostats, which are efficient a
reliable mechanically, are made available to the engine
to the same degree as the household refrigerator, then
can begin to think in terms of important engineering d
velopments in this area. The rewards are going to
enormous, particularly in the field of solid state devic
that can operate at temperatures between a few degrees
one hundred degrees absolute.

Industry News

(Continued from page 12)

SYLVANIA ESTABLISHES MICROWAVE DEVICE DIVISION

Sylvania Electric Products Inc., New York, N.Y., has announced the formation of a new operating division, the Microwave Device Division, to meet the rapidly expanding demand for complex "electronic age" components.

Sylvania President Gene K. Beare said that W. Herbert Lamb had been appointed vice president of the new division. Prior to his new assignment, Mr. Lamb had headed the Microwave Device Operations and the Picture Tube Operations within Sylvania's Electronic Tube Division.

The division has its headquarters, a microwave components laboratory, and a microwave physics laboratory at Mountain View, Cal., and a manufacturing plant at Williamsport, Pa.

—*mwj*—

RADIATION AT STANFORD AWARDED CONTRACTS TOTALING $1.6 MILLION

Under contracts totaling $1,651,000, Radiation at Stanford, Palo Alto, Cal., is building two 100,000 watt CW X-band transmitters and 1,000,000 watt power supplies for the USAF's space probing "Haystack" antenna system.

When completed in 1962, "Haystack" will be the most powerful radio research facility in the world. It will be capable of probing the surfaces of the moon or nearby planets such as cloud-enveloped Venus with a needle sharp beam, or if used as a radar will be able to detect a golf-ball size object 1000 miles away.

Radiation at Stanford originally received an $822,000 contract from the Electronic Systems Division of the USAF Systems Command for the first Haystack system. It was recently awarded the second contract for an identical system, plus changes in both to provide greater power capacity and flexibility of operation.

The facility, to be located at Haystack Hill, Tyngsboro, Mass., will be operated by Lincoln Laboratory of MIT.

—*mwj*—

WEINHOUSE NAMED CHIEF ENGINEER OF KEARFOTT MICROWAVE DIVISION

Norman Weinhouse has been named chief engineer of Kearfott Microwave Division, General Precision, Van Nuys, Cal., according to Willard B. Hughes, general manager.

Since joining the firm in 1958, Mr. Weinhouse has served as manager of the Systems Department and as manager of the Engineering Technical Office. In these positions he was responsible for the design of systems utilizing the microwave art, including radar test sets, monopulse radar systems, and microwave systems.

Prior to joining Kearfott, Mr. Weinhouse worked with Collins Radio for six years, leaving as manager of its Systems Engineering Group.

—*mwj*—

BOWEN NAMED SALES MANAGE OF RAYTHEON'S SORENSEN PRODUCT LINES

Raytheon Company, South Norwal
Conn., has named James D. Bowen
sales manager f
its Sorensen pr
duct lines, accor
ing to George
Estes, manager
Industrial Oper
tions.

Prior to joini
Raytheon, Mr. B
wen was Easte
sales manager f
Sola Electric C
and a sales en
neer for Sorensen & Co., Inc., bef
that firm was acquired by Raytheon C
in 1959. Earlier he was a design en
neer for E. I. DuPont, Wilmington, D

In his new post, Mr. Bowen will
rect sales of Raytheon's Sorensen li
of power supplies, voltage regulators,
verters and converters, frequency cha
ers, cable testers, meters and accessori

—*mwj*—

CANOGA C-BAND RADAR SUCCESSFULLY TRACKED "RANGER"

George H. Nibbe, president of Ca
oga Electronics Corp., Van Nuys, Ca
has announced that the Canoga mo
AN/MPS-26 C-Band tracking radar s
cessfully tracked the NASA RANG
spacecraft fired from Cape Canaver
Fla, August 23rd.

The Canoga radar, performing its m
sion of supplying digital trajectory da
acquired the RANGER as it rose abo
the horizon and tracked it for over 9
miles of its flight path.

—*mwj*—

(Continued on page 19)

3 WATTS at 1120 Mc from 7 WATTS at 140 Mc

A VARACTOR FOR EVERY PURPOSE

220 new epitaxial silicon high power varactors in four package styles — subminiature glass case • double-ended cartridge • "pill" case • new "coaxial pill" case — all hermetically sealed, make *this* kind of harmonic generation possible now.

A WIDE VARIETY of PIV ratings and capacitance values allows selection of the optimum diode in each case style for your circuit application.

The data reported below was obtained by the Waveguide Systems Division of Microwave Associates* in a tandem chain of three doubler stages, each using a selected single Microwave Associates' epitaxial silicon high power varactor.

This high power output and remarkable harmonic efficiency was achieved without boosters, without power supply, in passive circuits.

Since the initial introduction of varactors on a commercial basis by Microwave Associates, we have continued to lead the way in varactor technology.

Microwave Associates' unsurpassed varactor circuit capabilities are your assurance of varactors tested to meet specific harmonic generation requirements.

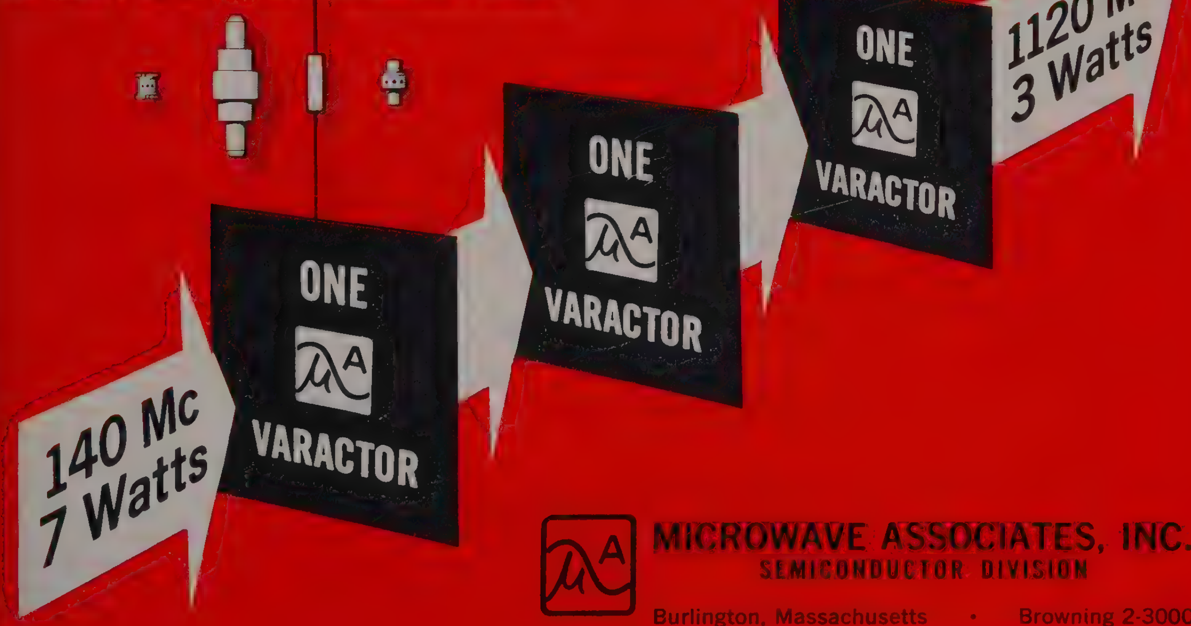
The Waveguide Systems Division of Microwave Associates offers capabilities for the design and delivery of complete harmonic generator circuits.

Write for a copy of "SELECTION OF VARACTORS FOR POWER HARMONIC GENERATION" and for the 1961 Semiconductor Division Short Form Catalog.

---

* Support received by (USAF) ETL Aeronautical Systems Division Contract #AF33 (616) — 7232.

with MICROWAVE ASSOCIATES EPITAXIAL SILICON HIGH-POWERED VARACTORS



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Circle Reader Service Card 9

SPERRY ELECTRONIC TUBE DIVISION microwave memo

Sperry extends 30-day delivery to cover ECM and augmenter TWT's operating in L, S, and X bands

In a dramatic extension of its capability for delivering high-performance microwave tubes on short notice, Sperry Electronic Tube Division has added three system-proved traveling wave tubes to the list of those available in 30 days. Included in the move are tubes operating in L, S, and X bands. They cover a frequency range 1.1 to 11.0 kMc.

APPLICATION FLEXIBILITY

The tubes in this series are particularly suited to application in augmenters and ECM equipment. The inherent broadband characteristic and unusual ruggedness of these PPM focused tubes makes them unusually versatile in airborne applications. A full course of MIL and environment tests, as well as considerable in-system experience have verified these characteristics.

INCREASED POWER POSSIBLE

Although these tubes nominally operate in the 1-2 watt power output range, optimum tuning can increase power to as much as 5 watts. A high-mu control grid adds to the versatility of these tubes by allowing remo switching, modulation control ar gain adjustment.

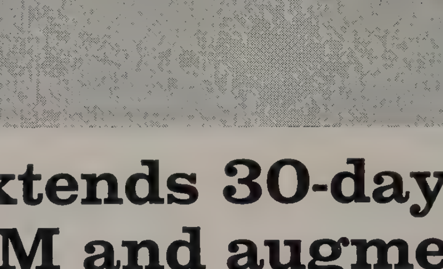
SYSTEM DESIGN SIMPLIFIED

Use of these Sperry tubes great simplifies system design problem Low voltage and high gain redu power supply requirements. Applic tion is further simplified, since amb ent cooling is sufficient in most app cations and the tubes may be mount in any position.

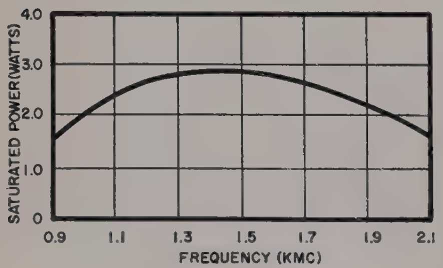
For FREE technical information on the Sperry Traveling Wave Tubes, write Section 602, Sperry Electronic Tu Division, Gainesville, Florida.

The L-Band tube is priced at $1,90 the S-Band tube at $2,195., and th X-Band at $2,540.

For application assistance and qu tation, consult your nearest Cain Co. representative. His address an phone number appear on the opposi page.



Drive characteristics at mid-band for a typical Sperry ECM/augmenter TWT.



A typical saturated power versus frequency curve for an L band Sperry TWT.

SPERRY ELECTRONIC TUBE DIVISION

GAINESVILLE, FLA. / GREAT NECK, N. Y.
SPERRY RAND CORPORATION

Circle Reader Service Card 10

Inquire about Sperry Tubes from these convenient Cain & Company offices

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VI 9-6781

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N. Y.
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HN 6-0600

Chicago 45, Illinois
3508 Devon Avenue
OR 6-9500

St. Petersburg, Florida
410 — 150th Avenue
Madeira Beach Prof. Bldg.
391-0151

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Albuquerque, New Mexico
Phone 268-5300

San Francisco, California
Phone YO 8-0995

San Diego, California
Phone HU 8-0665

Seattle, Washington
Phone MA 3-3303

SPERRY ELECTRONIC TUBE DIVISION
SPERRY RAND CORPORATION

Industry News

(*Continued from page 16*)

RADIATION AWARDED ANTENNA CONTRACT FROM BELL TELEPHONE

Radiation Incorporated, Melbourne, Fla., has announced the award of a contract from Bell Telephone Laboratories, Murray Hill, N.J., for the development, fabrication, and installation of two automatic-tracking antenna systems for use with the Bell System's experimental communications satellite.

The systems being provided by Radiation Incorporated will be installed at Rumford, Maine, and at Cape Canaveral, Fla. These antenna systems will be used to acquire, track, command, and to receive data from the satellite.

The contract specifies stringent requirements for antenna tracking rates, acceleration, tracking accuracy, high gain and low receiver noise levels. The antennas will utilize a four-helix array similar to those used on the Radiquad antennas developed by Radiation Incorporated for use on the first experiment in satellite communications — Project Score. These Radiquad antenna systems have since been used on the Pacific Missile Range and at other locations.

— m w j —

LANGBERG AWARDED FELLOWSHIP FOR STANFORD STUDY

Samuel Langberg, associate manager of the radar laboratory at Hughes Aircraft Company's ground systems group, Fullerton, Cal., has received an executive management fellowship for study at Stanford University in Palo Alto, Cal., Dr. Nicholas A. Begovich, company vice president and assistant group executive, has announced.

Langberg is one of 12 industry leaders throughout the country who have been selected to participate in the Sloan Business Executive Fellowship program at Stanford's graduate school of business which began September 18. The Stanford-Sloan program involves a nine-month period of intensive study and personal development featuring seminars, group and individual research and field trips.

Langberg, who is in charge of product engineering at the Hughes radar laboratory, has been with the company for nine years.

— m w j —

COLLINS ANNOUNCES ORGANIZATION REALIGNMENT

Collins Radio Co., Dallas, Tex., has announced the integration of all microwave activities into one organization within its new systems division, the Alpha Corporation. Simultaneously, the Company revealed that Alpha, formerly a subsidiary, has now become a division of Collins.

This realignment of Collins microwave activities will unite sales, systems engineering, contract administration, training and customer service under a new Director, Kerry R. Fox. In this new position, Fox will have responsibility for coordinating Collins entire marketing and systems effort for commercial as well as Government and International microwave and carrier sales.

— m w j —

PARLANTI APPOINTED TECHNICAL DIRECTOR AT GENERAL COMMUNICATION CO.

Dr. Conrad A. Parlanti has been appointed to the position of technical director for General Communication Co., Boston, Mass., microwave engineering and manufacturing firm. He will remain a vice president and member of the board of directors.

Dr. Parlanti holds several advanced degrees and is widely known in metallurgical circles through an important advance in molding technique which bears his name.

His broad industrial experience has included major technical and administrative responsibilities in a variety of areas, ranging from research and application of advanced metallurgical techniques to development and fabrication of specialized structures for critical military and industrial use.

His new duties give him overall responsibility in formulating the needs of the company on an expanded technical front, and in coordinating the development of specific engineering capabilities to meet those requirements.

— m w j —

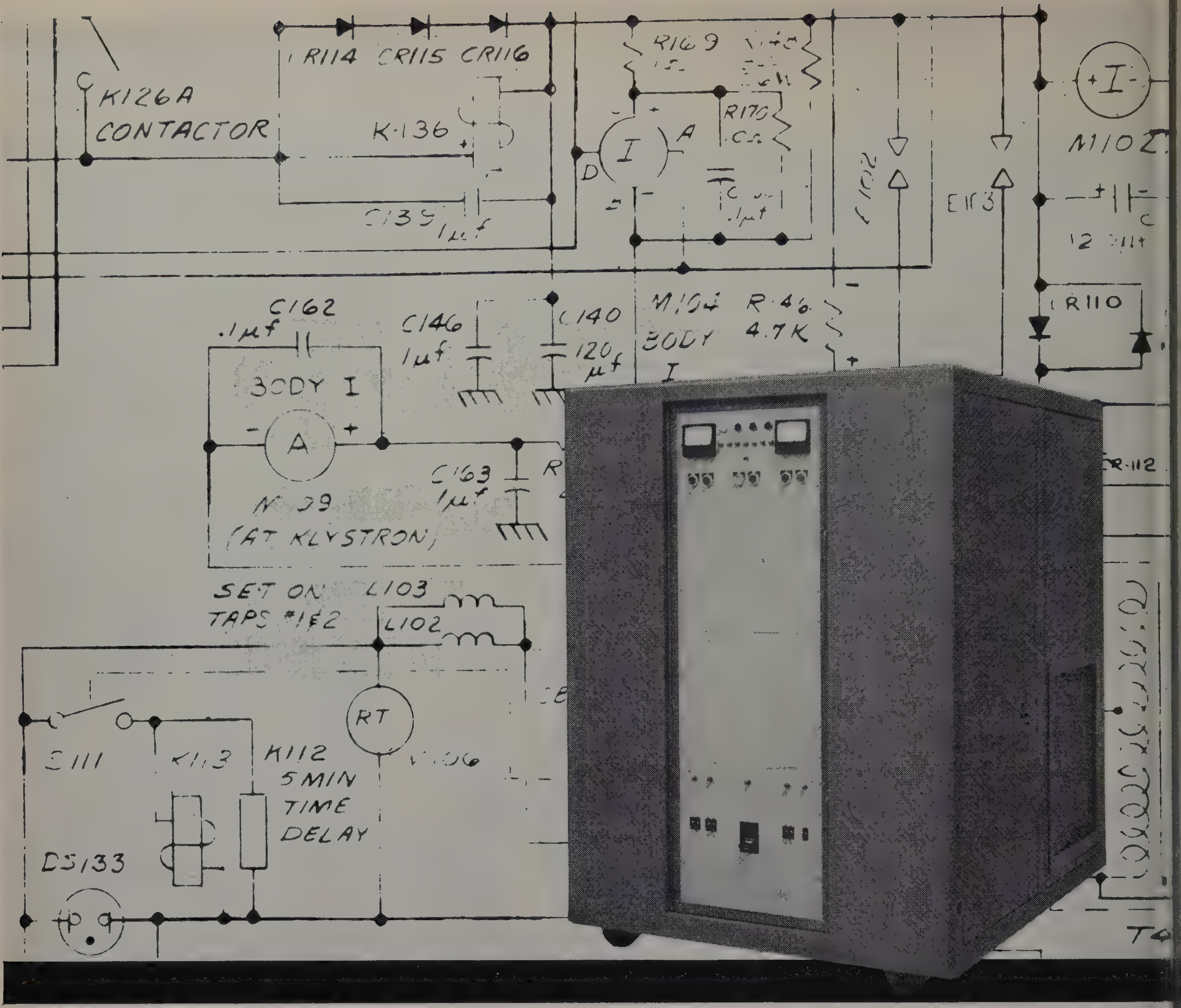
HOLLIS AND FREDERICK ELECTED DIRECTORS OF WHITE ELECTROMAGNETICS

James Hollis, president of Rixon Electronics, and Gordon Frederick, of Thompson Ramo Wooldridge, have been elected directors of White Electromagnetics, Inc., Bethesda, Md., it has been announced by Don White, president.

The firm, which recently changed its name from Don White Associates to White Electromagnetics, Inc., deals principally in RFI prediction and control, space communications systems and design, weapons system evaluation, system evaluation by computer simulation, and other phases of systems analysis.

— m w j —

(*Continued on page 23*)


K126A
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K-136
C139 1μf
R169
R170
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M110
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C162 .1μf
C146 1μf
C140 120μf
M104 BODY I
R46 4.7K
BODY I
A
M 99 (AT KLYSTRON)
C163 1μf
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RT
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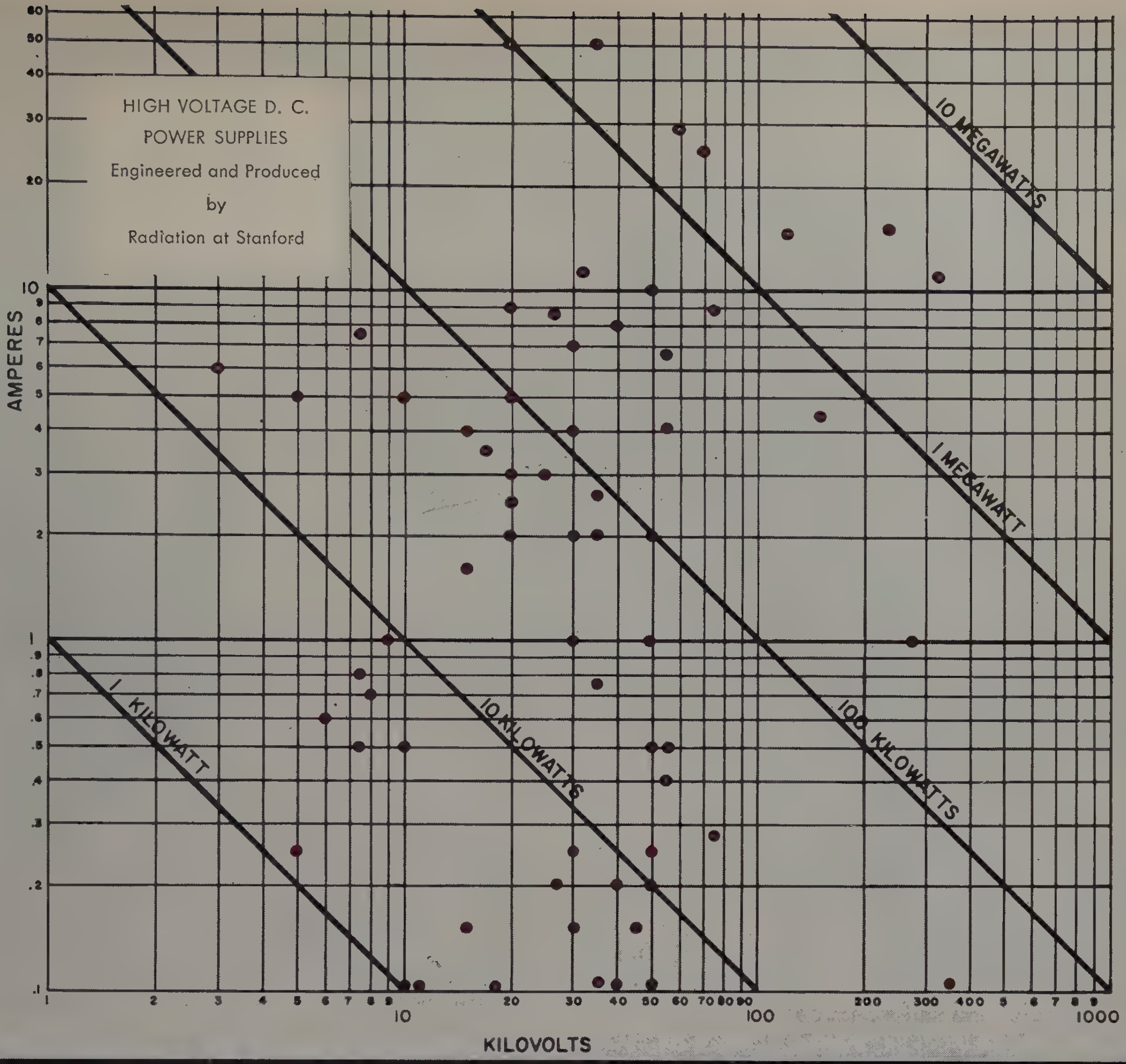
...STANDARD POWER SUPPLIES FROM 10 TO 600 KVA

Functional design is an important advantage of power supplies offered by Radiation at Stanford (formerly Levinthal). They are carefully engineered for rapid production of units with the exact characteristics you require.

Radiation at Stanford standard power supplies are distinguished by these features:

- Choice of output—10 to 600 kva; 10 to 55 kv
- Output continuously variable from 0 to full voltage
- Reversible output polarity
- Low ripple—down to 0.05%
- Protection against equipment damage and personnel hazard by complete set of interlocks with fail-safe indicators
- Protective circuitry for all meters against load short-circuit damage
- Circuit breakers throughout
- Magnetic component protection against over-voltage by spark gaps and auto-valves
- Simplified control—through use of "System ON-OFF," "High Voltage ON-OFF," and "High Voltage RAISE-LOWER" controls

For a special brochure with complete technical information on our standard line of "power" supplies, write Radiation at Stanford, 3180 Hanover Street, Palo Alto, California.



... AND CUSTOM SUPPLY SYSTEMS —ANY POWER YOUR PROJECT REQUIRES

The chart above shows the range of power supply units engineered and built by Radiation at Stanford. Many of these were for special one-of-a-kind applications. The "shotgun" pattern depicts a breadth of DC power supply experience that is unexcelled in the industry.

Among the custom units we have designed and produced are power supplies for some of the world's most powerful radar and radio telescope transmitters. Megajoule energy storage systems with ultra-fast crowbar protection are features of these units—and their performance is the measure of our capability in the super-power systems field.

If your project calls for unusual power and an early completion date, bring your problem to us. For specific information, call or write Radiation at Stanford, 3180 Hanover Street, Palo Alto, California.

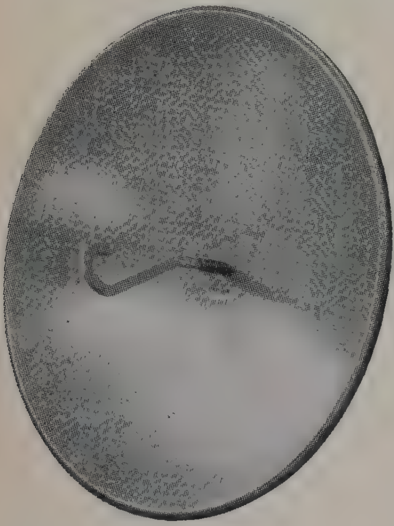
RADIATION
at Stanford

Circle Reader Service Card 11

From An Established Source...TELERAD

Antennas, Waveguide & Coaxial Components

Designed to meet the critical demands of modern R-F systems, Telerad parabolic antennas and waveguide components offer the utmost in engineering, materials, and craftsmanship. Telerad's test range facilities are in constant use measuring antenna patterns and power gain levels, supplying the most efficient equipment possible...whether it be for established designs, or for highly specialized new radar systems applications. Telerad antennas such as this incorporate a one-piece, spun aluminum reflector, which provides excellent dimensional accuracy while minimizing weight and installation problems.

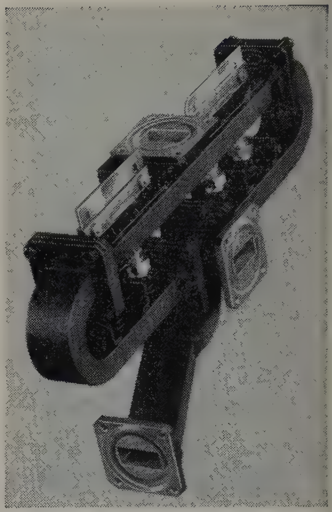


Other features:

- Unique backup structure provides a clean, undistorted reflective area.
- Furnished with a 7° adjustment for both azimuth and elevation.
- Comply with FCC specifications and EIA recommendations.
- Standard antennas cover frequency ranges from 5.9 to 16 KMC.
- Diameters range from 4 to 10 feet.

This is but one type installation; Telerad's capabilities include design and manufacture of many types and sizes for special requirements, such as helical, slotted arrays, dipole and horn antennas.

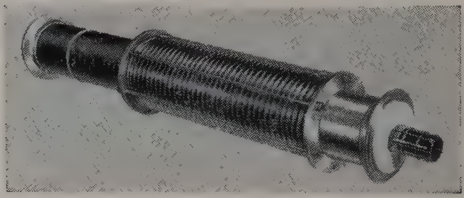
Telerad waveguide is available in four types: • Rigid • Flexible • Twistable • Pre-formed.



Rigid waveguide (Tele-Guide) is supplied in straight sections to 20-foot lengths, meeting all requirements of MIL-W-85C, and constructed of aluminum, brass, silver or magnesium. Choke and cover flanges are fabricated with strict adherence to MIL Specs. Tees, elbows, adapters, pressurized units, directional couplers, cavities, mixers and duplexers, rotary joints and special devices are catalog items. Each Telerad wav guide assembly is thoroughly inspected for end fittin alignment, pressure tightness, and VSWR before shipmen

These components are only a portion of the stock equi ment which Telerad offers. In addition, our engineerin and production facilities are highly capable of designin or custom-building specialized coaxial equipment f individual installations...

From components to complete microwave or rada systems: Tee Assemblies • Sweep Elbows • Rotary Join • Flexible Sections • Elbows • Adapters • Reducers Special Devices • *Plus*—High Power, Lightweig Aluminum Sections for Airborne Application.



We welcome the opportunity to discuss your special antenna, coaxial, and wavegui requirements...from individual components through complete front end assemblie

◆ Write Dept. 110-Y for new Telerad catalog covering expanded product line.

TELERAD

Route 69-202, Flemington, N. J.

Division of The Lionel Corporation

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(*Continued from page 19*)

NDERS ESTABLISHES ADVANCED OMMUNICATIONS LABORATORY

Sanders Associates, Inc., Nashua, N.H., s established an Advanced Communications Laboratory in Washington, D. C. The laboratory occupies a 4000 square-foot leased plant.

Laboratory operations will be devoted to research and development of sophisticated communications systems, de- ared Morton E. Goulder, Sanders' cor- orate scientist. Staffing the facility is ow underway, he said, with a nucleus Sanders engineers to be immediately gmented by adding senior scientists d engineers.

Lawrence W. Sharpe has been named ant manager for the new Laboratory. e was previously a member of the cor- orate staff at Sanders' Nashua plant. ior to joining Sanders he served as a rector of Army research and develop- ent programs and previously was direc- r of Airborne Research and Engineer- g at Cambridge Air Force Research enter.

Herman Brownstein has been appoint- to the post of chief engineer for the aboratory. He previously headed di- erse electronic research and develop- ent projects for the Department of De- nse.

— *mwj* —

PITOMETER LOG CORP. ELECTS NEW OFFICERS

The Pitometer Log Corp., New York, .Y., has announced the election of a ew management group.

Norton W. Mailman will head the oster as Board Chairman, his third such ost. He occupies similar positions at urroughs Manufacturing, Baltimore, nd at John Chatillon & Sons, New ork. Mr. Mailman is also president of e latter company.

New Pitlog president is Edward A. Ga- ski, who continues as president of Web- er Electronics and as secretary-treasurer John Chatillon & Sons.

Robert C. Rosaler, a six year veteran Pitlog, will remain as vice-president. reviously Mr. Rosaler held the posi- on of manager of the Mechanisms De- artment of Kearfott Division of Gen- al Precision Corp.

The Pitometer Log Corp. is involved development and production of elec- onics and electro-mechanical devices r the Air Force, Navy and for non- ilitary industrial and maritime appli- ations.

— *mwj* —

(*Continued on page 32*)

WJ-180 TWT
Power Supply

3.5 db
LOW-NOISE AMPLIFIER
IN S- AND L-BAND

Reliable performance in unattended field sites is achieved through the Watkins-Johnson low-noise preamplifier. Conservative design using solid state components offers a maximum of dependable service over varying environmental conditions. This rugged system is available per the following specifications:

Amplifier Model Number	Nominal Terminal Noise Figure (db)	Frequency (kMc)
WJ-111	4.3	2.0-4.0
WJ-111-1	3.5	2.1-2.4
WJ-111-2	3.4	2.3-2.7
WJ-111-3	3.9	2.5-3.5
WJ-112	4.0	1.0-2.0
WJ-112-1	3.6	1.1-1.6

Information in more detail available from representative in your area, or from Applications Engineering

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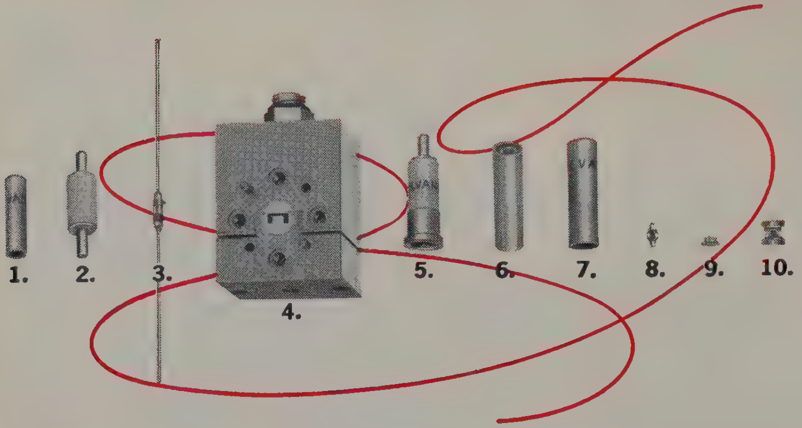
Sylvania offers the industry's most comprehensive line



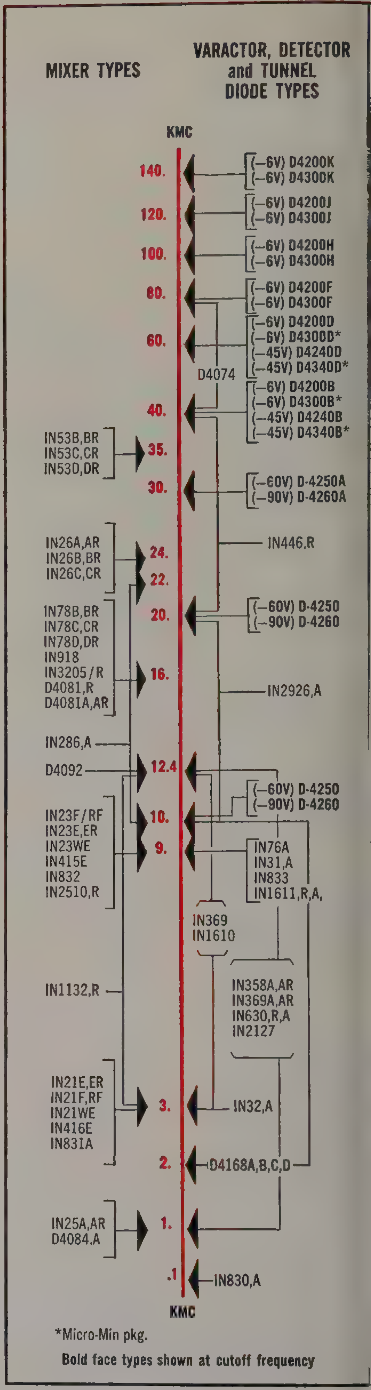
MIXER · DETECTOR · VARACTOR TUNNEL DIODES

100 MC TO 140,000 MC!

SYLVANIA MICROWAVE DIODES utilize the point-contact structure in those units specifically for Mixer and Detector service, and Mesa structure in the Varactor types. Tunnel Diodes are of germanium alloy construction and are packaged especially for operation at microwave frequencies as *mixers, amplifiers* and *oscillators*. Advanced processes and techniques developed by Sylvania assure Microwave Diodes capable of withstanding the most severe environmental conditions of shock, vibration and temperature. Extraordinary quality controls assure low-noise figures, high sensitivity and high Q where those characteristics are essential to equipment design.

If you are designing radar, countermeasure, missile control, TV or telephone relay, test or special-purpose equipment operating at microwave frequencies, send now for your copy of "Sylvania Microwave Diode Product Guide." This valuable new booklet contains data for more than 400 Sylvania Microwave Devices, the most comprehensive line in the industry. Write to Semiconductor Division, Sylvania Electric Products Inc., Dept. 351, 1100 Main St., Buffalo 9, N. Y.

For sales information on any Sylvania Semiconductor Device, contact your local Sylvania Field Office or your local Sylvania Semiconductor Distributor.



SYLVANIA MICROWAVE DIODE PACKAGES 1. Min-Coaxial 2. Double-Ended 3. Micro-Min 4. Waveguide Block 5. Cartridge 6. Coaxial 7. Tripolar-Coaxial 8. Micro-Min Varactor 9. Tunnel Diode 10. Pill Varactor

SYLVANIA

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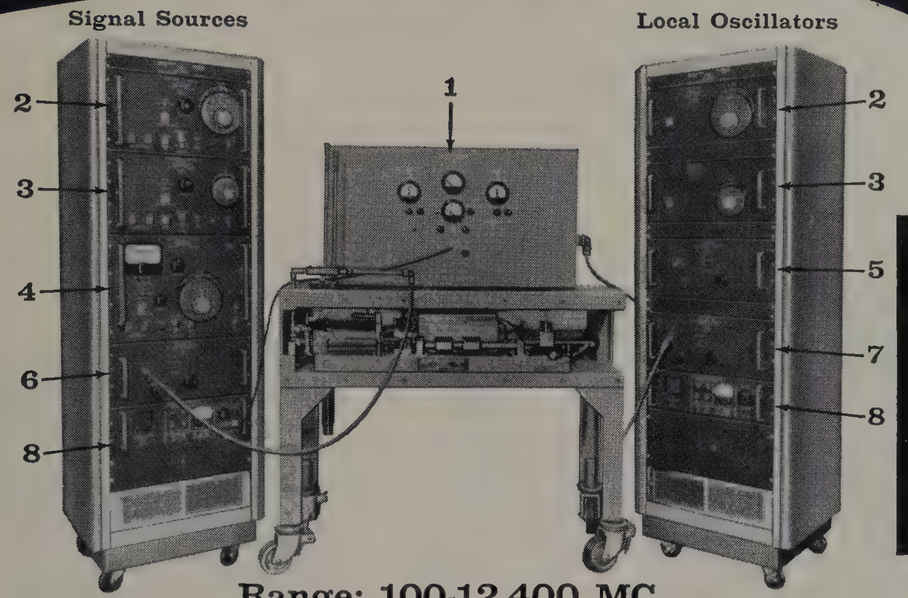
GENERAL SYSTEM

Complete Attenuation Measuring System

VM-1† by WEINSCHEL



1 VM-1
2 MS-12 50-250 mc
3 MS-13 250-920 mc
4 MS-3 900-2200 mc (self-contained)
5 MS-8 900-2200 mc
6 MS-9V 2100-4200 mc
7 MS-9 2100-4200 mc
8 MO-3 POWER SUPPLY MODULATOR

Range: 100-12,400 MC

Picture shows a complete system for the range 100-4000 MC. Signal sources and local oscillators to 12,400 MC available.

Iakes a 70 DB measurement vith 0.02 DB precision

This is the only complete working system commercially vailable from one source which offers standards labora-ry accuracy over such a great dynamic range. Each omponent is designed for compatability, resulting in ptimum systems performance. This Weinschel system oes perform:

- A 60 db measurement with an accuracy greater than 0.12 db starting with 20 millivolts (—21 dbm)
- A 120 db measurement with accuracy greater than 0.4 db starting with 2 volts (+19 dbm)

aves Time of Skilled Personnel

The VM-1 is **direct reading**, easy to use. No calibra-on curves or correction charts are needed. This **ease of peration** enables normally skilled personnel to perform uch of the work and still save many hours both in etting-up time and in measurement time.

Typical example of time saved for making eight 10 db step measurements of signal generator output attenuator or an external variable attenuator:

	Old Method		Using Weinschel VM-1	
	Time	Personnel Required	Time	Personnel Required
Set-up time for one frequency.	1 day	Highly skilled with experience	15 min.	Normally skilled operator with one week initial training.*
Measurement time	30 min.	Highly skilled with experience	3 min.	No technically skilled operator required.

* Installation and training at customer's laboratory by a Weinschel specialist is included with each system purchased.

Typical Uses of the VM-1

The VM-1 attenuation measurement system is designed for use in **standards laboratories.** It can also be used in **precision testing** on a 100% basis in certain **production** applications where state-of-art accuracies are required (e.g., radar fuzing systems, guidance and satellite communications systems). It is also used in the **calibration** of output attenuators of **signal generators.**

Patent applied for.

For complete information on the VM-1 Attenuation Measuring Systems, call or write the Application Engineering Department, Weinschel Engineering Company.

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free space conditions, to eliminate radar-distorting reflections, and to create year-round al
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MICROWAVE ABSORBERS BY B.F.Goodrich

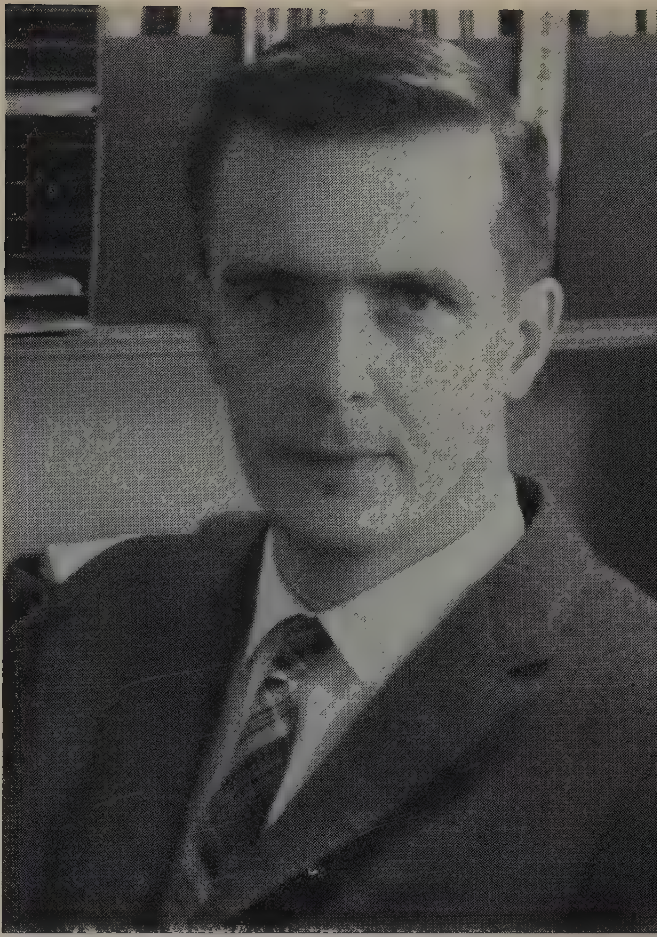
Circle Reader Service Card 15

DWIGHT CASWELL

President

CASWELL ELECTRONICS, CORP.

San Jose • California



By WILLIAM HESTER

In 1953, a full page advertisement in the January issue f the *Proceedings of the IRE* caused a tremendous stir n the microwave community. A newly-formed company, Cascade Research, was offering for sale a new product alled a Uniline. If this new ferrite device performed as he specifications in the advertisement indicated, it would evolutionize the microwave industry. Cascade was flooded with letters of inquiry and even received a few orders.

Cascade Research was Dwight Caswell. In 1952, he and erry Jaffe were engineers at Hughes and felt they could evelop better components than Hughes was able to purhase for microwave systems. Working nights and weeknds at home, they were able to make what they felt would be a saleable product. Feeling confident that he ad something special, Dwight left Hughes and in Noember, 1952, started Cascade Research in Los Gatos, California. It was incorporated in December with Dwight Caswell as President and, as indicated, ran its first adertisement in January. Jerry Jaffe left Hughes in mid-953 to devote all his time to Cascade.

At first they had problems. The original isolator had een developed after many nights of hard work, and the weary engineers had not noticed that their test equipment was drifting. When orders came, they tried to duplicate he specifications they had quoted and immediately realized heir difficulty. Again they put in long hours and after 85 starts managed to achieve the advertised specifications. They had been so engrossed with the electrical problem, owever, that they neglected to consider the package deign or the label. When the first units were complete, Mrs. Caswell painted and lettered them by hand, and Cascade Research was in business.

Dwight Caswell is a native of Oregon. He was graduated from the University of Oregon where he majored in physics, following in the footsteps of his father, Albert Caswell, who was a physics professor there. Dwight received his B.S. in 1943 and entered the Navy as an officer assigned to the Naval Research Laboratory in Washington. His father had left the University earlier to help the war effort at M.I.T.'s Radiation Laboratory.

During the three years Dwight was in the service, he was liaison officer for the sound division and traveled to Navy installations and laboratories all over the country, but not to M.I.T. He became very familiar with the Navy's underwater sound work, but felt that sound was not a satisfactory means of detection. This was one field he would not consider for a career when he got out.

In 1946, Dwight enrolled at Stanford for graduate work. Again his choice was influenced by his parents' background. They had both gone to Stanford. His father was, in fact, the first student to receive a Ph.D. in Physics from Stanford. However, Dwight was also influenced by an earlier meeting with Dr. William Hansen. While Dwight was still a high school student in Oregon, the Caswell family visited San Francisco to attend the World's Fair there. Of course, the elder Caswells had to show Stanford to their children. Dwight recalls being impressed by Dr. Hansen and seeing his rumbatron. This was before the Varians had invented the klystron.

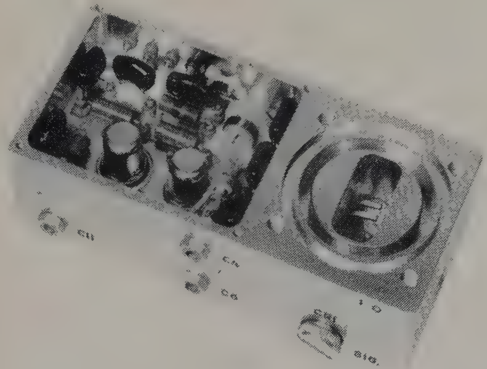
At Stanford, Dwight Caswell majored in nuclear physics and was one of the early workers on the linear accelerator. He worked under Dr. Hansen with Dick Post. The

(*Continued on page 28*)

got a mixer-preamp problem?

Whatever your problem in the application of microwave receiving equipment LEL can answer it with off-the-shelf hardware of practical up-to-the-minute engineering design — and performance that's just plain hard to beat.

The mixer-preamplifier illustrated is the newest of more than 800 stock models available for use throughout the microwave frequency range. The XBO-8 combines a Transfield Mixer and a Nuvistor preamplifier, providing excellent noise figure, small size and very low power drain.



Series XBO-8

SPECIFICATIONS

Frequency Range	8.5-9.6Gc
Gain	22db
IF	30, 60 or 70mcs
Bandwidth	8mcs
Noise Figure	Less than 8db
Power	+40 VDC at 12ma 6.3 VAC at 0.4amp
Size	1⅞" x 1⅛" x 4"

Send for 48 page illustrated Catalog— "Microwave RF/IF Equipment".

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CASWELL

(*Continued from page 27*)

latter is now with Project Sherwood. After Hansen's death, Russell Varian worked on the project for eight months. "I hope something of Hansen and Varian rubbed off on me," Dwight remarked in recalling this part of his education. Dwight received his M.S. in Physics in 1950. The work he had done was written up in the Reviews of Scientific Instruments at that time.

After receiving his masters degree, Dwight was interviewed by a number of companies. One of these was Hughes in the Los Angeles area. Preferring to remain near Stanford, Dwight asked for what he thought was an outlandish salary. But Hughes agreed, and he felt he couldn't afford not to take it.

While at Hughes, Dwight Caswell worked on the microwave package for the Falcon missile. The radome wasn't exactly his job, but he felt that the best radomes available were not good enough. So he took over radome development and invented a method of minimizing radome errors by using metal discs. In a similar manner he managed to stick his hand in the development of every part of the microwave circuitry. It was this same dissatisfaction with existing components which led to the founding of Cascade Research.

Cascade was financed by Caswell, Jaffe, and a few friends for a total capitalization of $20,500. For the first two years, there was no competition, and profits were good. The company grew. "I was surprised by the growth daily," says Dwight. "In fact," he adds, "I am still amazed at the continuing growth of the microwave industry." But when competition moved in, the company went into a loss position for six months.

Recalling it now, Dwight Caswell feels they made three errors: (1) They had no adequate plan for long-term financing; (2) funds were diverted outside of ferrites; and (3) they lacked the realization of the magnitude of the microwave market. To protect the interest of the other stockholders, Cascade merged with Monogram Precision Industries. Caswell now took the title of Director of Engineering.

In January, 1959, Dwight left Cascade when the management announced that it would be moved to the Los Angeles area, a move Dwight had opposed for some time. Jerry Jaffe is still with Cascade.

On March 16, 1959, two months after he left Cascade, Dwight started his present company, Caswell Electronics, with Fred Hall, whose successful business background furnishes balance to the organization. With the lessons learned from Cascade, the company is run on a sound financial basis and is thriving.

Dwight Caswell has presented technical papers at many conferences and has several patents to his credit. He is member of the Physical Society and a senior member of the I.R.E. He belongs to the professional groups on microwaves, antennas, and management.

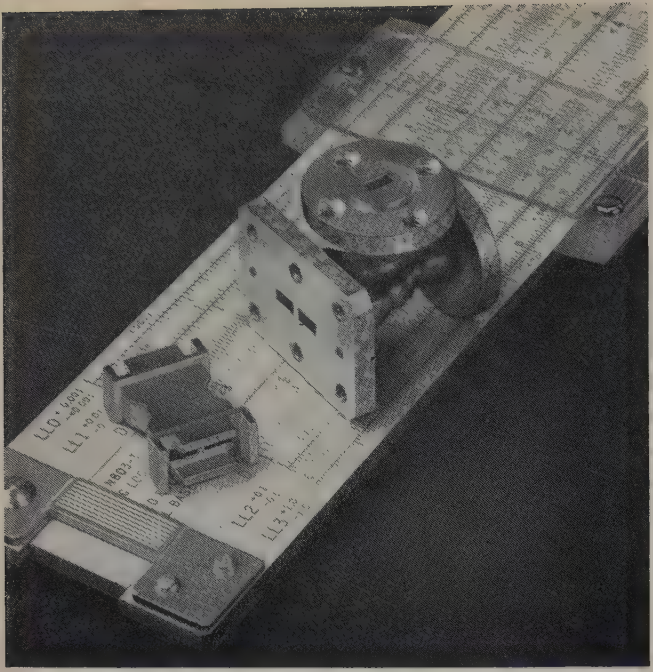
Dwight married a high school classmate, Helen Rayburn, in 1942. They have five children ranging from 1 down to two. The middle one is the only girl. The Caswells live in Saratoga in the same house they bought in

(*Continued on page 30*)

lew Eimac UHF-TV klystron pushes costs way down!

ow available: Eimac's 4KM100LA, a new 25KW klystron designed for UHF-TV transmitters. It rovides the lowest operating cost ever with its low unit price, long life, non-critical focusing and high ain of 30 db to replace three tetrode stages! What's more, it's a complete amplifier unit and needs no RF esign work, water filters, expensive maintenance. The 4KM100LA has all this and low noise too—more an 60db below black level. No wonder Eimac klystrons are used in almost 90% of all European UHF-TV ations! And now Eimac anticipates *your* needs with this modern, cost-cutting tube. or more data write: Power Klystron Division, Eitel-McCullough, Inc., San Carlos, Calif.

imac 4KM100LA Klystron Simultaneous Operating Characteristics. Beam voltage: 16KV; Beam Current: 8A; Power Output, peak sync.: 25KW; Bandwidth: 8mc, 1db; AM Noise: greater than 60db down.



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(V-band) components
STOCK DESIGN
available promptly

SIDEWALL HYBRID COUPLER

- Frequency range: 68.0-72.0 GC
- Unbalance: 0.25 db max.
- Isolation: 30.0 db min.

"H" PLANE HYBRID TEE

- Frequency range: 67.0-73.0 GC
- Unbalance: 0.25 db max.
- Isolation: 35 db min.
- VSWR: 1.3 max.

Other components in WR15 band to your specific requirements. Write for engineering bulletin.

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Circle Reader Service Card 18

Ski binding poses a problem for niece Kathy Caswell, so M
Caswell pauses to repair it. His son Philip is in backgroun

CASWELL

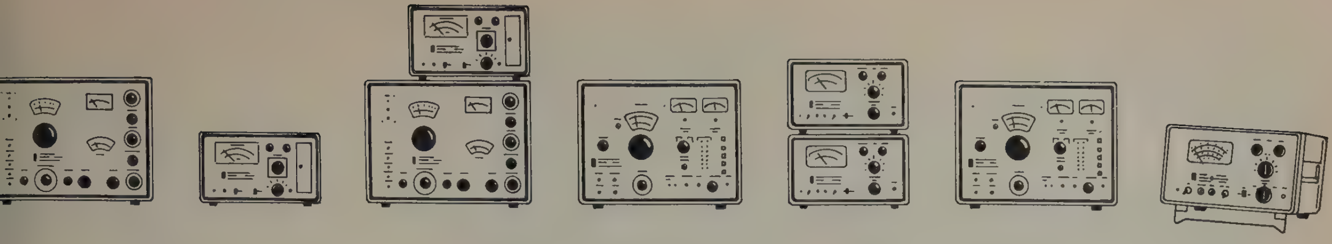
(*Continued from page 28*)

1952, when Cascade was started in nearby Los Gatos. is an old house, built in 1880, a rarity in California.

Mrs. Caswell is a professional portrait painter. She also a well-known poet and has won many poetry prize Next year Knox Press will publish a book she has writte a full-length narrative poem.

All the Caswells enjoy hiking and camping. Five yea ago, Dwight had to make an extended business trip on tl West Coast. Mrs. Caswell drove to Quebec with her fo children (the youngest was three), camping along tl way. Dwight flew to Quebec to meet them after his bus ness was done, and the whole family drove and camp down the Eastern seaboard and back to California by southern route. Now, as soon as the youngest child old enough, the Caswells are planning a camping trip Alaska.

Dwight Caswell's main interest, outside of his famil is Caswell Electronics. "I don't have a hobby," he say "because if I did, it would be building something as amateur. Here at Caswell Electronics, I'm building som thing professionally." Because he is never satisfied wi the status quo, Dwight Caswell will continue buildir and he and Caswell Electronics will both grow professio ally.



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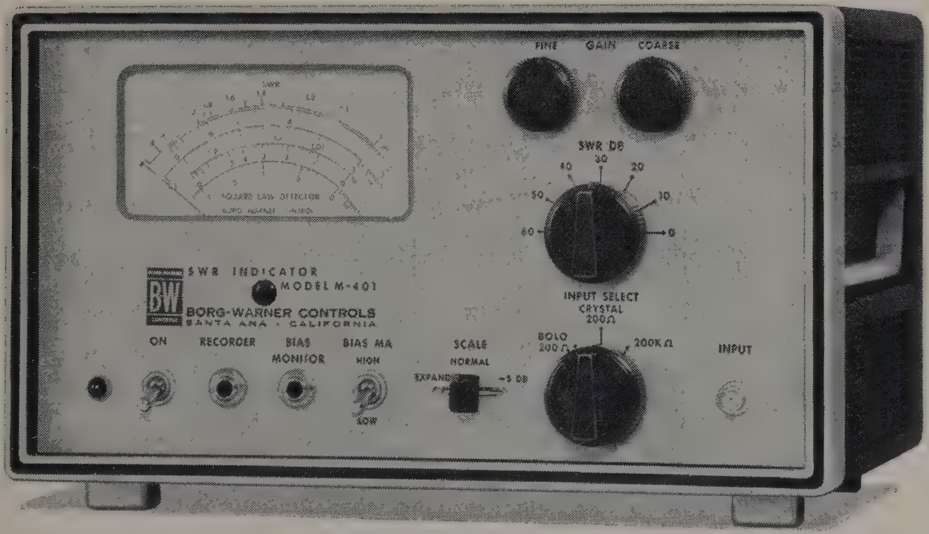
Now, a fresh new approach to precision laboratory test instruments...designed and engineered by Borg-Warner Controls to meet the most demanding needs of industry. The result of 15 years of leadership in high-power radio-frequency equipment, these new instruments are superior in styling...in convenience and versatility...in accuracy and performance. Clean, functional design. Handsome two-tone brown and beige color schemes. Simplified controls—no crowding or confusion of knobs. Finest quality meters for quick, clear, accurate readings. Most important of all, better resolution due to improved design. Don't buy any laboratory quality test equipment until you've examined these advanced new models!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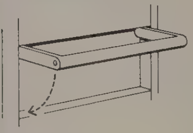

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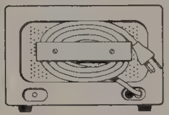

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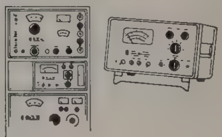

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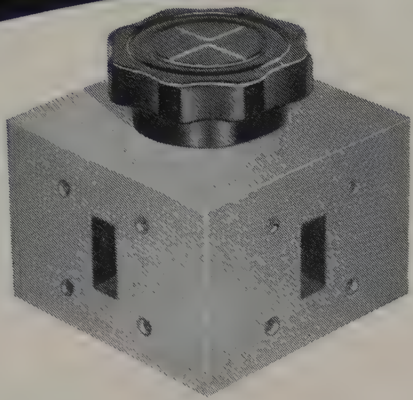

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378-E	3.95 to 5.85	RG-95/U
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578-E	7.05 to 10.00	RG-68/U
678-E	8.20 to 12.40	RG-67/U
778-E	12.40 to 18.00	RG-107/U (AL)
878-E	18.00 to 26.50	RG-66/U (AL)
1078-E	26.50 to 40.00	RG-96/U (AL)

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(*Continued from page 23*)

WESTERN ELECTRONIC ASSOCIATES FORMED IN CALIFORNIA

Western Electronic Associates, sales engineering representatives, has been formed with its main office at 5351 Lemon Avenue, Van Nuys, Cal., and branch offices to be opened in San Diego and San Francisco.

Western Electronic Associates is comprised of three field engineers stationed in the key electronic areas of Los Angeles, San Francisco, and San Diego.

The company is devoted to speciali ing in the representation of products i the radar and microwave fields, ke noting microwave solid state device backward wave oscillators, traveling wav tubes, waveguide test equipment, an other such microwave equipment an components that will be represented i the future. The company provides an maintains a complete mailing list an office facilities for efficient represent tion.

Western Electronic Associates present represents three companies in the microwave field: namely, Geisler Laboratorie Woodland Hills, California; Quant dyne, Los Angeles, California; and Microwave Semi-conductor and Instrumen Corporation, Richmond Hills, New Yor (The latter company is represented b WEA in the Northern part of Californi only.)

—*mwj*—

HARMAN ELECTED PRESIDENT OF JERROLD ELECTRONICS

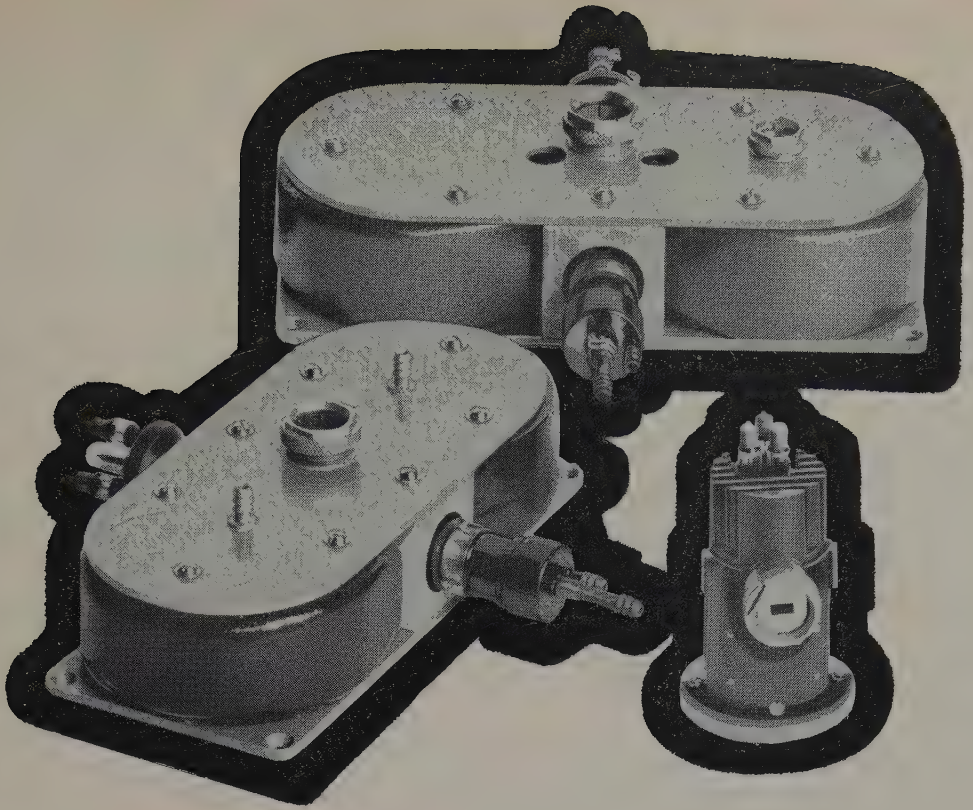
Jerrold Electronics Corp., Philadelphia, Pa., has announced the election of Sidney Harman as president and chief executive officer. He succeeds the company's founder, Milton J. Shapp, who remains chairman of the board of directors.

Mr. Shapp, who has become increa ingly active in recent months as a co sultant to the Kennedy Administratio will continue his participation in co pany affairs on a policy-making level.

Mr. Harman was president of Harma Kardon, Inc., manufacturer of high delity instruments and electronic comp nents for data processing, when the co pany merged with Jerrold Electron last February. He was elected executi vice president of Jerrold in April.

—*mwj*—

(*Continued on page 34*)



Ku-BAND TO 80 KMC

LONG-LIFE MILLIMETER WAVE KLYSTRON TUBES FROM LITTON

or applications in the 18-80 kMc range, the Litton Electron ube Division now offers the Elliott-Litton line of quality-ngineered millimeter wave tubes.

he floating drift tube design used for most Elliott-Litton lystron oscillators produces the effect of a single-cavity tube ith the working efficiency of a two-cavity klystron. **Additional dvantages of this design are freedom from hysteresis, stability f operation, and exceptionally low thermal drift.** Reflex lystrons are available in the 12 and 8 millimeter regions.

pplications include radar and communication systems, signal ources for microwave spectroscopy, gaseous plasma experiments, high-stability pumps for masers or parametric amplifiers, nd local oscillators.

ontact us at San Carlos, California, for more information on lliott-Litton tube types or on any of an extensive array of itton microwave and display tubes and accessories.

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L-3689	68 - 80	1500	0.500 average	Liquid
L-3690	68 - 80	1500	0.100	Liquid
L-3691	68 - 80	1500	0.100 average	Liquid
L-3640	48 - 52	Fixed	1.0	Liquid
L-3693	48 - 52	1500	1.0	Liquid
L-3629	33 - 37	Fixed	15.0	Liquid
L-3628	33 - 37	1600	10.0	Liquid
L-3632*	33 - 37	1000	0.030	Air
L-3633*	33 - 37	1000	0.200	Air
L-3659	32 - 37	700	5.0	Liquid
L-3697	30 - 37	1600	1.5	Liquid
L-3698	30 - 37	1600	1.0	Air
L-3630	21 - 25	Fixed	10.0	Liquid
L-3631	21 - 25	1000	8.0	Liquid
L-3642*	18 - 25	400	0.100	Air
L-3692*	18 - 25	400	0.350	Air
L-3699	21 - 25	1000	1.5	Liquid
L-3700	21 - 25	1000	1.0	Air

* REFLEX KLYSTRON

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Electron Tube Division
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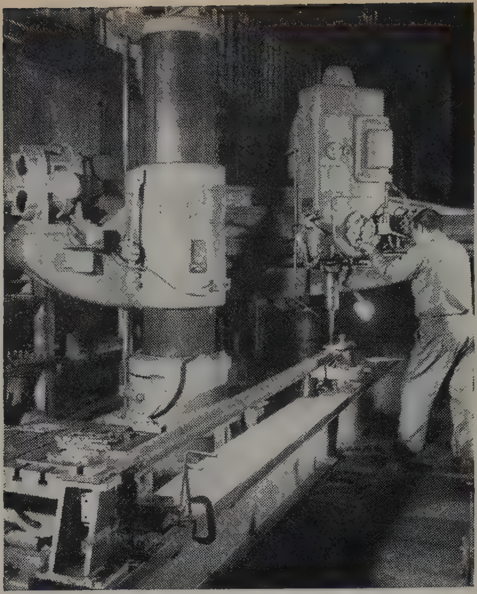

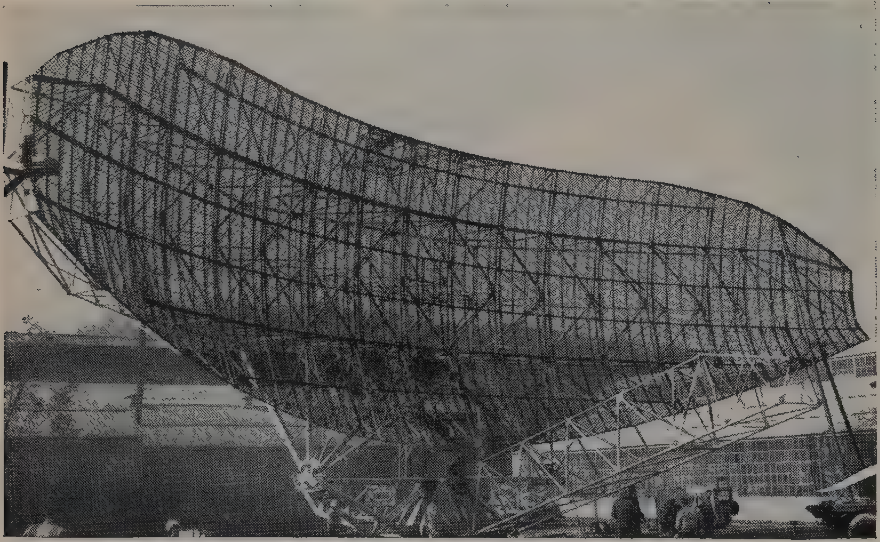

U.S.A.F.'s FPS-35 Radar Antenna, built for Sperry Gyroscope Co.

Blaw-Knox skill in fabricating intricate structures to close tolerances makes possible even greater accuracy in the operation of radar antennas, tracking antennas or radio telescopes. Highly developed manual skills and skillful operation of machine tools assure better fit in these large, but extremely precise instruments.

It is the master-craftsman skills at Blaw-Knox, plus Blaw-Knox's unique shop facilities and years of fabricating experience, that produce close-tolerance instruments. And Blaw-Knox engineering skills assure the right design to make the best use of those facilities and that experience.

Blaw-Knox designs and produces antennas to close tolerances with minimum deflections at reasonable cost — fabricates in steel, special alloys and aluminum — designs to your needs or builds to your specifications. Complete research, engineering, testing and fabricating facilities are at your disposal. Write or phone for immediate attention. Blaw-Knox Company, Pittsburgh 38, Pennsylvania. Phone STerling 1-2700.

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Industry News

(Continued from page 32)

NAVY STUDY PACT FOR TRANSISTORS AWARDED HUGHES

A $125,000 study contract for investigation of high frequency transistors and circuits has been awarded Hughes Aircraft Company's semiconductor division, Newport Beach, Cal., by the U.S. Navy's bureau of ships, Dr. Earl L. Steele, manager of the division's development laboratory, has announced.

Goal of the research program is to determine the feasibility of development of an amplifier, mixer or harmonic generator for operation at frequencies within the region of 4,000 to 10,000 megacycles, frequencies at which transistors have not yet operated, Dr. Steele said.

"Hughes physicists have evolved a theory concerning negative-resistance effects at high frequencies. With a transistor designed to enhance these effects in a package designed for microwave frequencies it is theoretically possible to achieve the desired frequencies in suitable circuits," Dr. Steele said.

— m w j —

RADIO CONFERENCE TO BE HELD IN CHICAGO

Requirements and problems pertaining to the Department of Defense Electromagnetic Compatibility program will be main topics on the program of the Seventh Conference on Radio Interference Reduction and Electronic Compatibility.

Conducted by the Armour Research Foundation, the conference will be held on the Campus of the Illinois Institute of Technology on November 7, 8, and 9. Sponsored jointly by the three military services, the conference is conducted in cooperation with the Institute of Radio Engineers' professional group on radio frequency interference.

With emphasis placed upon the analysis requirements of the DOD Electromagnetic Compatibility Analysis Center being implemented at Annapolis, Md., the program will attract representatives from government and industrial activities, both at the practical and more technical levels.

Included in the program will be sessions on electromagnetic compatibility analysis, design and measurement techniques, data processing and display methods, interference prediction techniques, and practical interference control and reduction. Civilian as well as military interference problems will be included in the program. A one-day session for presentation of classified papers is being planned.

Herbert M. Sachs, ARF assistant director of the electromagnetic compatibility facility is the conference chairman.

Inquiries regarding the conference should be addressed to William McGee, Conference Secretary, Armour Research Foundation, 10 West 35th St., Chicago 16, Ill.

— m w j —

(Continued on page 36)

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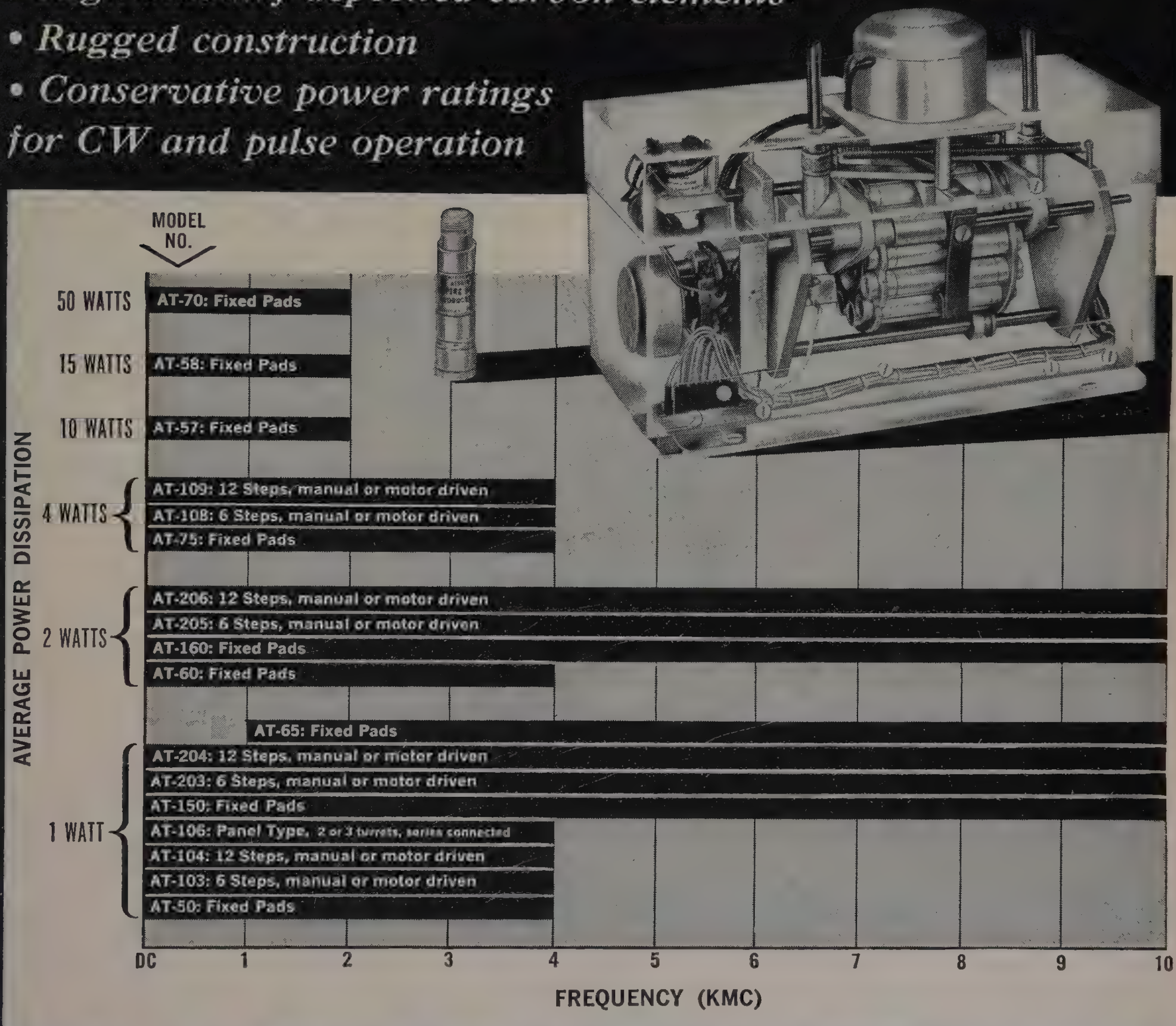

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ruggedness . . .
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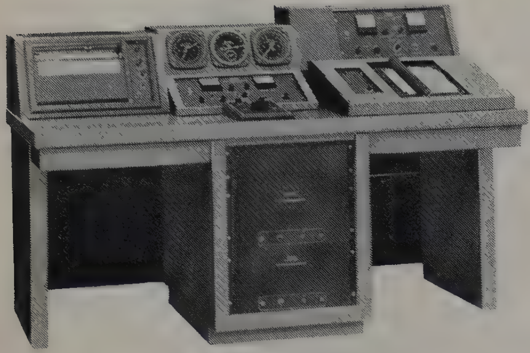
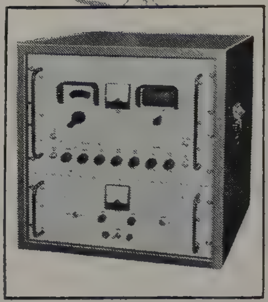
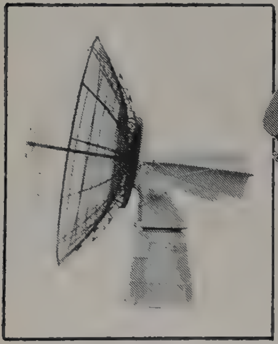


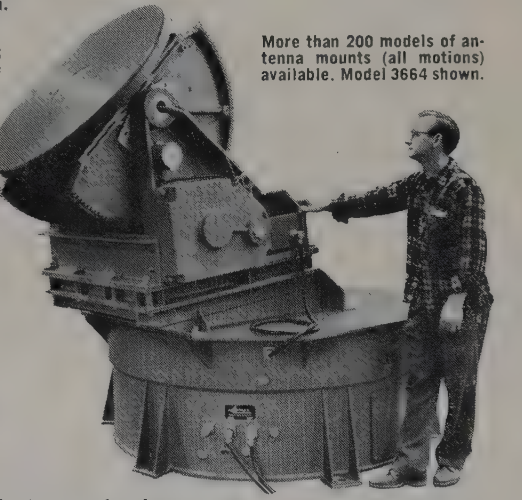
Recorders and other electronics available in many console variations. Model 604 shown.



Model 2040 MICROWAVE RECEIVER provides high sensitivity, excellent linearity and ease of operation with broadband performance over a wide dynamic range.



Full line of totally enclosed tracking pedestals. Model 7625-20W shown.



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Circle Reader Service Card 24

Industry News

(*Continued from page 34*)

TANQUARY HEADS RF TRANSMISSION COMPONENTS SECTION OF EIA

Grafton P. Tanquary, director of marketing for the Components Group o Litton Industries, Inc., Los Angeles Cal., has been named chairman of the RF Transmission Components Section the Electronic Industries Association Washington, D.C.

The section, a part of EIA's Industrial Electronics Division, was recently established to deal with management problems in the fields of antennas, waveguides, and coaxial cables. It works closely with the EIA Engineering Committee on Waveguides and Transmission Lines.

Mr. Tanquary, the 13th man hired when Litton Industries was founded in 1953, has spent most of his Litton career managing various microwave activities. Before joining the Components Group when it was established two years ago, he was general manager of the corporation's ferrite devices activity.

— m w j —

ALBONE HEADS NEW PRODUCTS DIVISION AT MCS

Norman Albone has been appointed manager of the New Products Division of Microwave Components and System Corp., Monrovia, Cal., according to an announcement by Gene Draper, chief engineer.

Mr. Albone has had more than 1 years experience in the microwave field Before joining MCS, he was superviso of customer service for the microwave division of Kearfott Div. of General Precision, Inc., Van Nuys, Cal., for one year. Prior to that he was a microwave engineer for Raytheon Company, Oxnard, Cal., and a sales engineer for two years at DeMornay-Bonardi, Pasadena Cal.

Mr. Albone attended California Polytechnic at San Luis Obispo. He is member of the I.R.E.

— m w j —

MASER OPTICS ACQUIRES TRIDENT

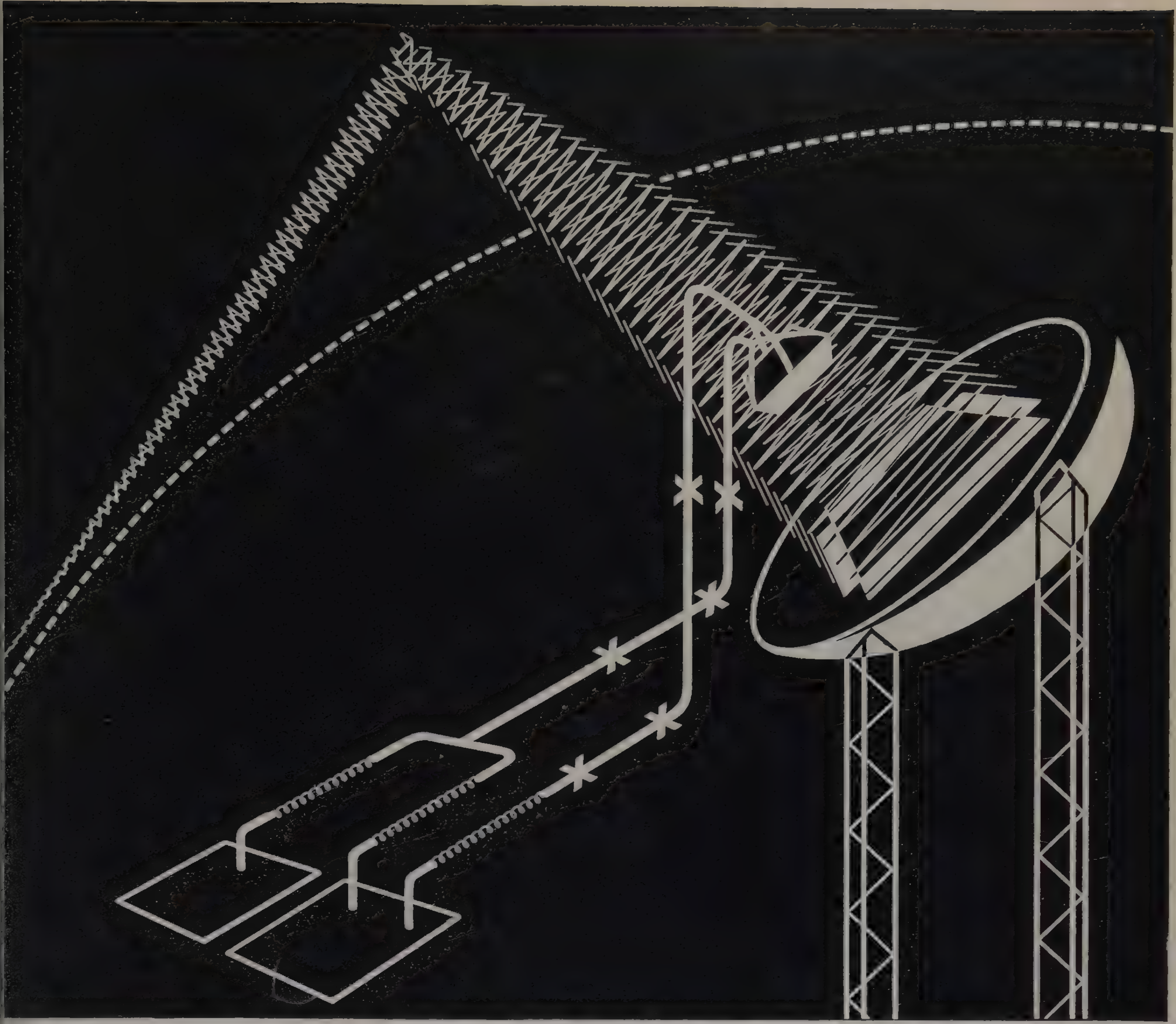
Maser Optics, Inc., Boston, Mass., has announced the acquisition of Trident Corp., Cambridge, Mass., through purchase of all capital stock.

Maser Optics performs research and development in the field of radar and laser devices. Trident Corp. is an engineering and manufacturing organization producing new equipment for laser research, optical radar, and underwater detection.

All personnel have remained with Trident under the new acquisition. Maser Optics is now adding to Trident's staff additional scientific personnel, who are currently engaged in development work with lasers and masers.

— m w j —

(*Continued on page 42*)



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From diplexer to antenna, I-T-E engineers are specialists in tropospheric scatter communication systems built to the most exacting requirements yet demanded by the state of the art. These systems assure reliable "beyond-the-horizon" communication for commercial and military services. Diplexer and attendant filters, large waveguide components, articulators, feedhorn and antenna are assembled and tested to provide a combination of components in a system with the minimum cumulative VSWR.

An example of I-T-E's attention to detail is the development of articulators that provide ample flexibility for expansion of the waveguide run and positioning of the feedhorn without a change in VSWR value. Accurately fabricated large waveguide, from WR430 to WR2300, assure greatest power handling capability at a minimum VSWR. And I-T-E's Twin-Tee* dual-polarized feedhorns and antennas complete the many troposcatter systems now in service.

In the broad capabilities of I-T-E's Special Products Division are accomplishments in other related fields. Developments in resonant rings and comparable test devices are just a few of the examples of complex I-T-E microwave systems in large waveguide. Information on this specialized service is available by calling GArfield 6-5700 or by writing I-T-E Circuit Breaker Company, Special Products Division, Department MJ, 601 East Erie Avenue, Philadelphia 34, Pennsylvania.

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SPECIAL PRODUCTS DIVISION

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LETTERS TO THE EDITOR

ditor, *the microwave journal*
330 Beacon Street
rookline 46, Mass.

ear Sir:

The interesting article on the traveling vave resonator in *the microwave journal* of eptember 1960 provides an excellent ba- is for challenging one widely held con- ept regarding spectrum analyzers.

In describing Figure 13 the author states, Figure 13 shows the spectra of the driver ulse, ring forward wave, and load wave. hese may be interpreted as representing plot of average power density versus fre- uency." The average reader will accept his as a valid interpretation; however, he ring spectrum presents a very good case or a different concept of the operation of spectrum analyzer that provides a differ- nt interpretation.

Obviously the power that is built up in he ring as it is charged is at only one requency, the resonant frequency of the ing, and after the build up is completed he stored energy passed on to the load uring the decay of the ring wave will be t the same frequency. Thus the sample of he ring power that is fed to the spectrum nalyzer consists of pulses having the form f the ring wave and at a single frequency.

In some spectrum analyzers the input gnal is converted to a lower frequency ut without change of form before it is ixed with the output of the swept os- llator of the analyzer. During one ex- ursion of the frequency of the swept os- llator the frequency is a little higher ach time another signal input pulse oc- urs. Thus the output from the mixer is sequence of intermediate pulses having he same shape of envelope as the signal nput pulses but at progressively higher equencies.

Near the middle of the sweep of the pectrum analyzer one of the intermediate ulses is at the resonant frequency of the nput circuit of the narrow-band amplifier f the analyzer. This intermediate pulse roduces the maximum transient response rom this amplifier and makes the highest ne in the display on the cathode ray tube. ince the preceding and following intermediate pulses differ from the amplifier enter frequency in varying degree, the ransient response of the amplifier to these ulses is correspondingly less and the other nes of the display have corresponding ower amplitudes.

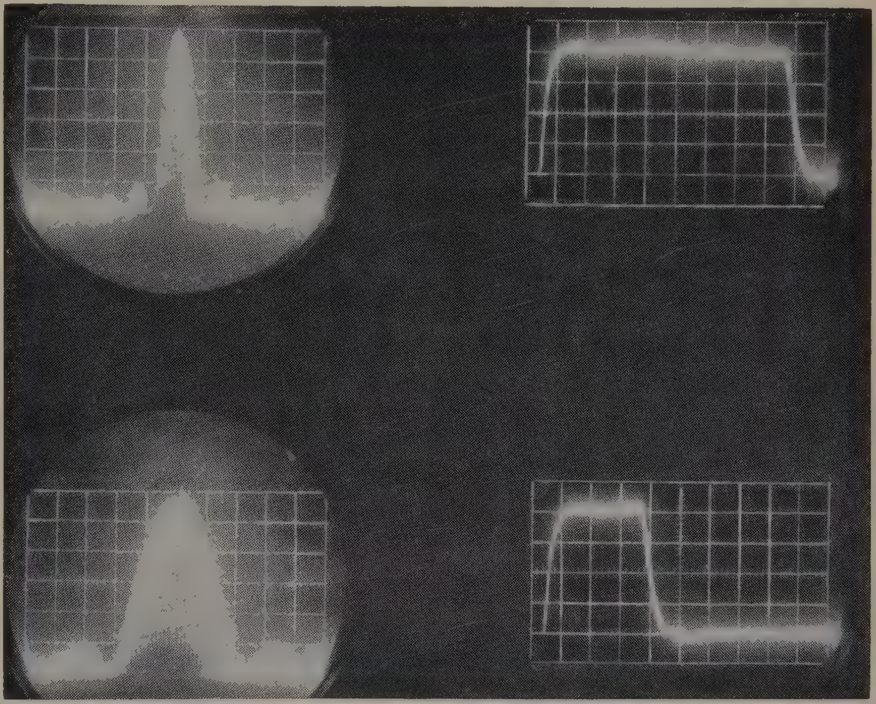
The lines in the ring spectrum of Figure 3 represent a measure of the output of he narrow-band amplifier of that particu- ar analyzer when the input to the ampli- er is a series of intermediate pulses having he form of the ring wave in Figure 12 nd the frequency of each pulse slightly igher than that of its predecessor. In ther words, this so called "spectrum" epresents a sort of frequency response haracteristic of the narrow-band amplifier for one particular form of signal input. It does *not* indicate the frequency distribution of the power in the ring.

This concept of spectrum analyzer operation has three factors that are important in determining the shape of a "spectrum display." The basic factor, explained above, is the effect of the changing frequency of the swept oscillator. The other two factors are the wave form of the intermediate pulses, a form derived from the input signal, and intra-pulse frequency variation in the intermediate pulses, which is also derived from the input signal. This last factor accounts for the appearance of two peaks in the "load spectrum" in Figure 13.

This concept of explaining spectrum analyzer operation on a physical rather than mathematical basis may raise violent objections from Fourier followers.

Very truly yours,
Robert W. Cushman
Newtown, Pa.

— *m w j* —



Editor, *the microwave journal*
1330 Beacon Street
Brookline 46, Mass.

Dear Sir:

I have read Mr. Cushman's letter with interest. I have also tried to reconcile his arguments with my understanding of the operation and purpose of a spectrum analyzer but without success. The fundamental point of contention is in the fifth paragraph of Mr. Cushman's letter. I would prefer to consider that as the local oscillator sweeps over its frequency band it periodically encounters a component of the signal such that $/f_{sig}-f_{lo}/=f_{if}$. Since these signal components have amplitudes which are dependent upon the form of the signal, a variation in the amplitude of the output of the amplifier results. This argument, needless to say, presupposes the acceptance of Fourier transforms.

To support my argument I submit the enclosed photograph. It shows two detected RF pulses beside their respective spectra. The only thing changed was the pulse length, the repetition rate being the same in both cases. All controls of the spectrum analyzer were untouched except for the vertical gain which was reduced slightly for the longer pulse situation to keep the display on scale because of the increased duty cycle. The sweep time was 1μs/cm so that we have pulses of 3.2 and 8.2 μsec. The corresponding spectrum widths are exactly inversely proportional to the pulse widths. I do not see how their behavior, that is the decrease in spectrum width with increasing pulse length, can be explained in other than Fourier terms* and certainly not in the manner which Mr. Cushman suggests.

---

* *A complete physical explanation of the spectra, expressed in terms of a physical concept in the time domain, has been received from Mr. Cushman. Copies of this are available to interested readers.*

By applying the normal interpretation of spectrum amplifier presentations to my Figure 13 and relating it to the physical situation, one arrives at a consistent interpretation of the results. Restating the interpretation of my Figure 13 in slightly different terms from the paper one can argue as follows:

The input to the ring circuits consists of energy distributed over a frequency band in a manner determined by the input pulse length and repetition rate. The ring being a resonator of finite Q, and therefore bandwidth, responds to a portion of this input signal resulting in a narrow frequency distribution of energy within the ring. Since the ring acts as a frequency absorption filter between the input and load, the energy in the load shows the input less that absorbed in the ring.

In conclusion, I believe Figure 13 can be explained only in the frequency domain and any attempt to relate the time domain shapes of Figure 12 to the spectra of Figure 13 by any means other than Fourier transforms is in error.

Very truly yours,
Stanley J. Miller
Staff Member, Group 46
Lincoln Laboratory
Lexington 73, Massachusetts

— *m w j* —

Editor, *the microwave journal*
1330 Beacon Street
Brookline 46, Mass.

Dear Sir:

My copy of Stan Miller's letter to you has been received. Apparently the oversimplification of my spectrum analyzer concepts in my letter of October 18th left room for Mr. Miller to make some incorrect assumptions in trying to fill in the missing parts, a situation which I shall try to correct in a more detailed letter to him.

The excellent photograph of spectra that he has supplied provides a very good example for me to use in explaining my concept. If I am successful, I believe Mr. Miller will want to revise his statement after he has had an opportunity to consider the implications of my concepts in the time domain more fully.

Sincerely yours,
Robert W. Cushman
Newtown, Pa.

— *m w j* —

Editor, *the microwave journal*
1330 Beacon Street
Brookline 46, Mass.

Gentlemen,

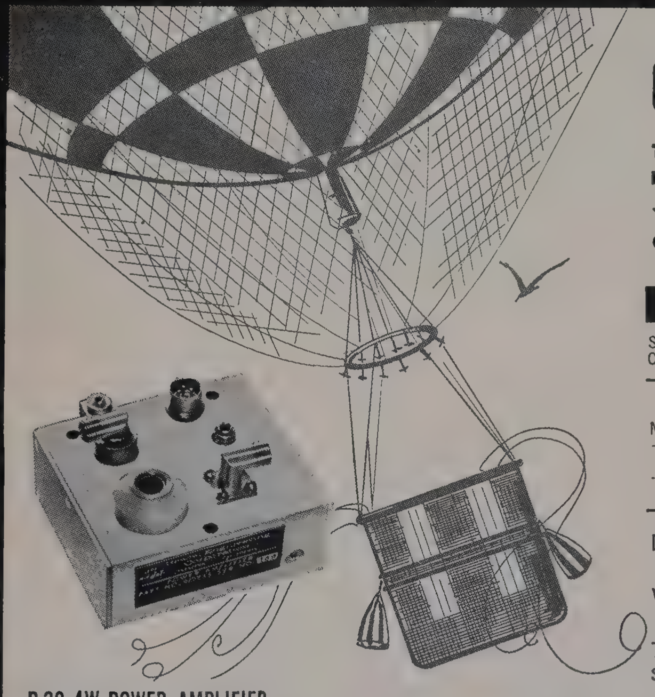
In recent issues of *the microwave journal* I have read, with interest, art cles and editorials relating to the bus ness aspects of our industry. Eac brought to light a different aspect the many problems which make up th whole. Each article noted an underlyi theme of worry.

We worry lest our engineers get th urge to leave, we worry that we are able to justify research costs as we ma not get production and we worry abo the growth rate of the company again the rest of the industry. One thi which did not get mentioned and whi I believe should be of worry and hone concern is the fact that we may n be worrying about making decisions whe they are needed. Many of the proble of our industry, as well as others, cou be resolved or prevented by receiving decision in time to permit action. T say decision by default is damnable conservative at least.

A saying whose author is unkown me should be painted for all to see . . 'To be a leader you MUST make dec sions!'

Very truly yours,
William S. Finberg,
Great Neck, New Yo

— *m w j* —



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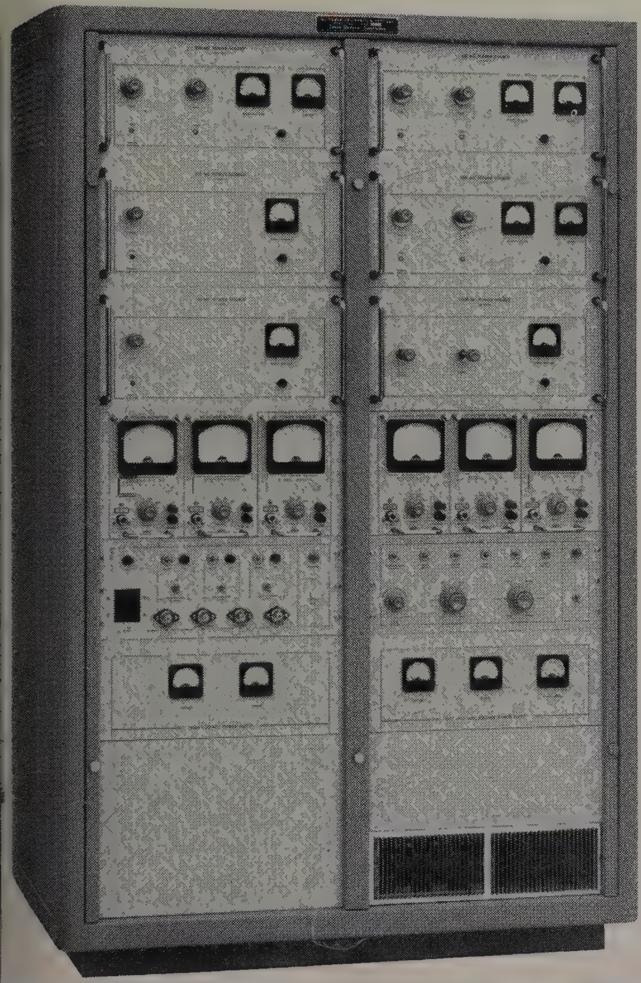
Tele: MUrray 1-07689 SYcamore 5-5197

Send for free literature

Circle Reader Service Card 27

SIX POWER SOURCES

Unique accuracy and dependability



in a versatile new Sierra RF Calibration Test Set

Think of the many applications YOU have for a single system that gives you variable power to 125 watts at RF frequencies of 30, 100, 300, 400, 500 MC, to 60 watts at 1300 MC!

Besides being able to calibrate many forms of power-measuring devices to 1% accuracy (0.5% probable accuracy), you can use this test set as a convenient precision source of high-power RF for applications such as antenna and interference measurements.

Sierra Model 1223 includes six power sources, six power monitors, power and frequency selector unit, blower unit, control unit and two regulated power supplies—all housed in a 19-inch double rack.

The crystal-controlled power sources are highly stable, providing frequency accuracy within 0.01%. For calibrating calorimeters, bolometer and thermistor type power meters, and other devices for detecting RF power levels, just connect the device, select the frequency and power level, and compare the device reading against the known power of the test set. A factory-furnished potentiometer and voltage/power table provides additional calibration accuracy over the panel-mounted power meter.

The six unique power monitors, one for each power source, attenuate harmonics and deliver dc voltage proportional to incident RF to the front-panel meter and potentiometer. Special design of a directional coupler and thermocouple detector help maintain the calibration of the monitors over a long period of time. Once calibrated, a repeatability of 0.5% can be expected.

Special control circuits protect the test set; indicators assure the operator of proper test set operation and monitor output voltages and current drains. Simple removal of individual rack-mounted units speeds calibration and routine maintenance.

Write today for complete information.

SPECIFICATIONS

Frequencies:	30, 100, 300, 400, 500 and 1300 MC
Frequency Accuracy and Stability:	± 0.01%
Power Ranges*:	Six ranges (5, 15, 30, 60, 100 and 125 watts) for five lowest frequencies; four ranges (5, 15, 30 and 60 watts) at 1300 MC; all power levels adjustable by vernier control to at least ± 10% of nominal range. Vernier resolution is greater than 0.25%
Power-Monitoring Accuracy:	± 1% maximum error with potentiometer measurement, and ± 4% (full scale) maximum error with panel-mounted meter. Probable (rms) errors are 0.55% and 2.5%, respectively
Output Impedance:	50 ohms
Recommended Max. Load VSWR:	1.5 to 1
Harmonic Content:	At least 50 db below fundamental frequency
Dimensions:	68″ high, 42.5″ wide, 20″ deep
Price:	$15,000.00

*Internal adjustments allow power ranges to be adjusted to any desired coverage.

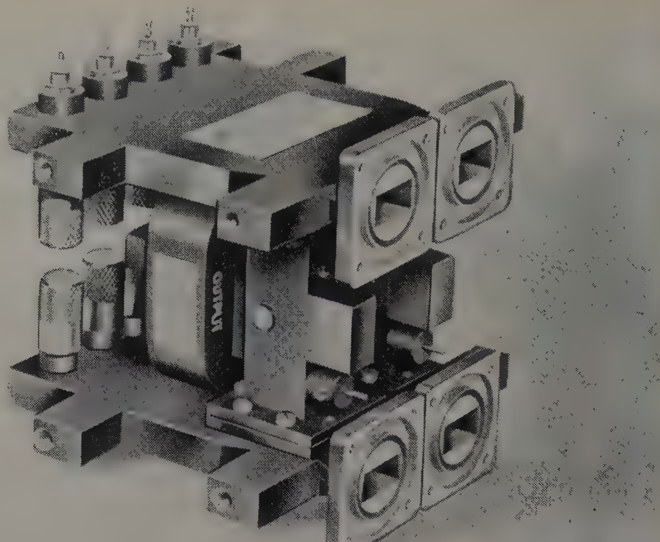
Data subject to change without notice. Price f. o. b. factory.

sierra

SIERRA ELECTRONIC CORPORATION
A Division of Philco Corporation
7197C BOHANNON DRIVE • DAVENPORT 6-2060 • AREA CODE 415 • MENLO PARK, CALIF., U. S. A.
Sales representatives in all major areas
Canada: Atlas Instrument Corporation, Ltd., Montreal, Ottawa, Toronto, Vancouver
Export: Frazar & Hansen, Ltd., San Francisco

7197

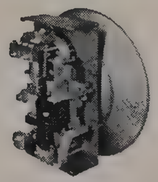
Circle Reader Service Card 28

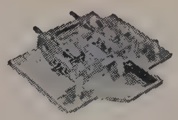


PACKAGED PRECISION
FOR YOUR EXACT REQUIREMENTS

MICROWAVE SUB-SYSTEMS

Kearfott has the experience and ability to design precision sub-systems to the customer's actual configuration and performance needs. The availability of a wide variety of standard components, coupled with advanced techniques, makes it possible to provide packaged r-f assemblies with a high component density—tailored to precise volumetric specifications. For minimum size and weight in airborne or missile applications — for military system environment—Kearfott will successfully design your sub-system —to your most exacting requirement.


Mono-Pulse Radar


S-Band Strip-transmission Head

Mixer Duplexer

High Power Mixer Duplexer

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

Circle Reader Service Card 29

Industry News

(*Continued from page 36*)

POLARAD AWARDED $4 MILLIC CONTRACT

The Bureau of Ships of the U.S. N
has awarded Polarad Electronics Co
Long Island City, N.Y., a contract in
cess of $4,000,000 to furnish a quan
of AN/URC-32 Single Sideband Sh
to-Shore Transceivers and auxiliary eq
ment.

The AN/URC-32 is a combined tr
mitter-receiver designed for shipbo
installation. Covering the frequencies
from two to 29.9 Mc, it features si
sideband transmission of 500 watts, w
is equivalent to 4,000 watts a-m, in
audio frequencies of 200 to 2,600
cles.

The unit is crystal-controlled throu
out its entire transmission spectrum
is accurate to one part in a million. T
ing is in increments of one kc.
sensitivity of the receiver is one mi
volt with a 10 db, signal-to-noise ra

—mwj—

AMPHENOL-BORG COMBINES F RF PRODUCTS DIVISIONS UND BLAIR

Amphenol-Borg Electronics Co
Broadview, Ill., has announced an
pansion in the f
of radio freque
energy, with
phasis on the
crowave portion
the spectrum.

"As part of
program," M
thew L. Dev
president, sa
"the compa
two divisions
the field, FXR
RF Products, have been combined
an enlarged unit to be known
FXR, with Neil M. Blair as divi
president."

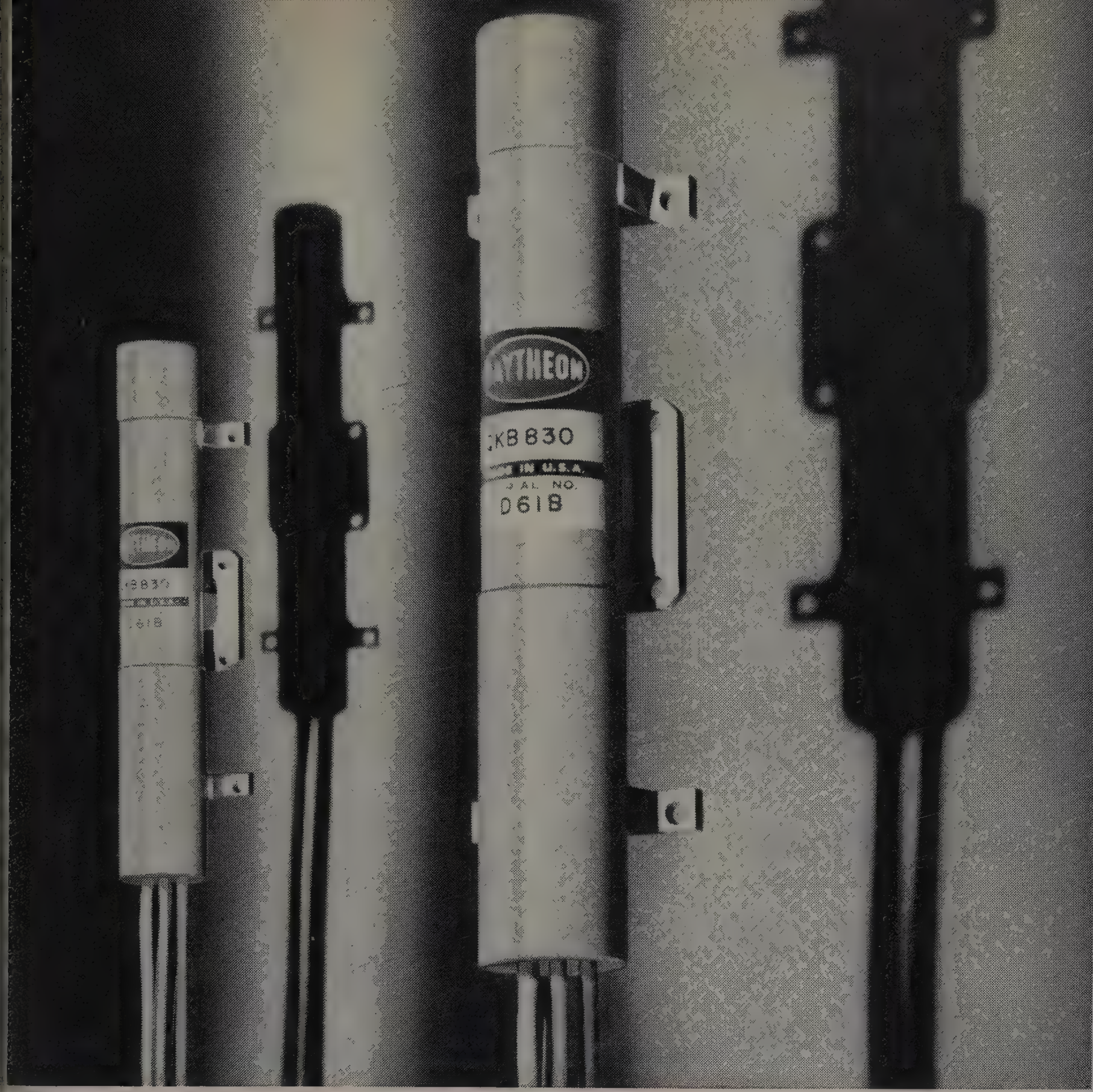
Mr. Blair headed the former RF
ducts Division in Danbury, Conn.,
a cable and wire facility in Chicago.
also assumed operating direction
FXR's 150,000-square foot factory c
plex in Woodside, N.Y., when
phenol-Borg acquired FXR earlier
year.

According to the announcement, D
bury will serve as headquarters of
new division.

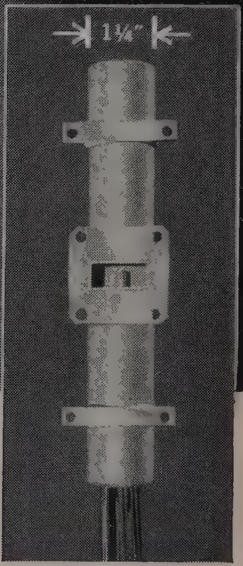
Mr. Blair described the new FXR
a "multi-plant, multi-product divis
second in size only to the Conne
Division in the Amphenol-Borg fami
It offers, he said, "a broad capability
the design, manufacture and applica
of components, test equipment and
systems associated with the generat
transmission and utilization of radio
quency energy, with increasing emph
on the microwave portion of the
spectrum."

—mwj—

(*Continued on page 46*)



QKB 830 O-TYPE BWO
1¼ inches in diamete
weighs only 1½ lbs.



Electrostatically focused BWO provides smaller, lighter X-band signal source

New Raytheon tube combines advantages of backward wave oscillators in rugged compact package ideal for airborne and missile use.

The QKB 830 is especially suitable for local oscillator service in airborne, shipboard, or ground-based equipment such as anti-jam radar receivers. A wide-range tube, it can be tuned from 8.5 to 9.6 kMc by varying a single electrode voltage.

The small size and low voltages of the QKB 830 permit its use as a direct replacement for mechanically tuned klystrons in existing systems. It is also adaptable to many other applications requiring a voltage tunable source having provision for low-voltage pulsed or amplitude modulation.

Write today for technical data or application service to Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts. In Canada: Waterloo, Ontario.

QKB 830 GENERAL CHARACTERISTICS
(Typical CW Operation)

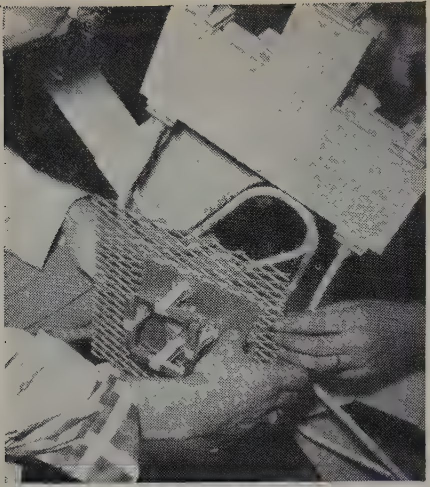
Power Output	15-30mW
Frequency	8.5-9.6 kMc
Voltage Requirements	
Tuning Voltage	150-250 Vdc
Focus Voltage	300 Vdc
Filament Voltage	6.3 V
Shock	50 G's
Cooling	convection
Overall Length	7.5 in.
Weight	1.5 lb. Max.

RAYTHEON COMPANY

RAYTHEON

MICROWAVE AND POWER TUBE DIVISION

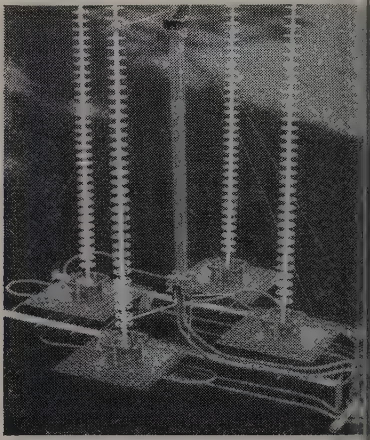
Circle Reader Service Card 30



Individual unit assembly is first step in construction of antenna. Here four dipole antennas mounted on ground screen are being connected to one end of Foamflex feed lines. Special Phelps Dodge connectors are used to link the lines to the dipoles and four-way power dividers.

Completed quadrant elements, ready for placement on p mount. Each quadrant is pre-assembled in exactly the same

Completed quadrant elements are raised to platform for placing into position on pedestal mount.



An example of a center element u can be inserted into the Avien-Bogne This element forms a separate unit t also be used as a portable ultra hi quency antenna.

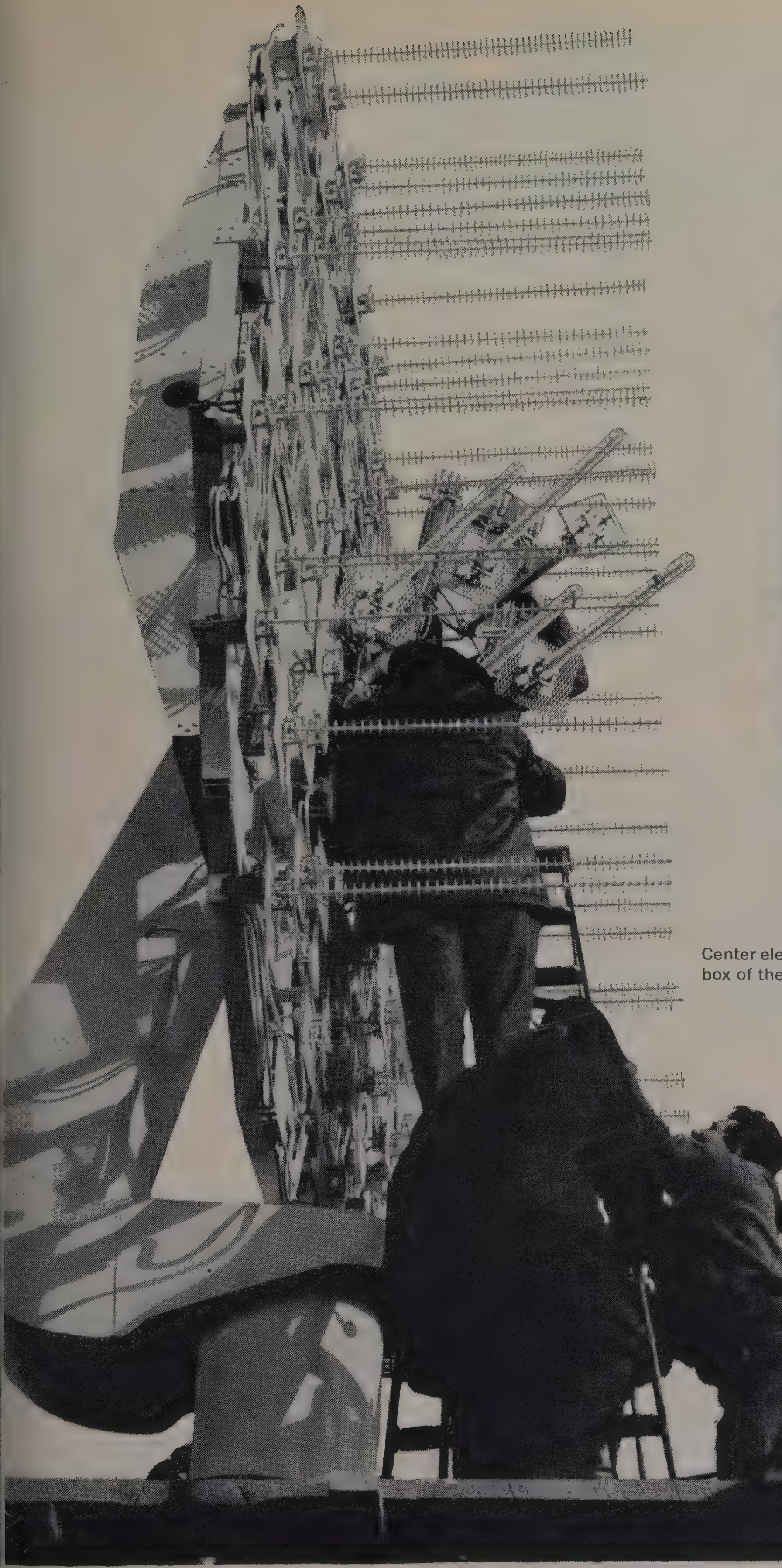
Foamflex® Coaxial Cable helps put and ke this advanced antenna system on the trac

A feed network of ⅜″, 50 ohm Foamflex coaxial cable is a critical part of the fully automatic Avien-Bogner acquisition and tracking antenna that represents an advance in the state of the antenna art. The efficient operation of this sensitive antenna is greatly increased by the low loss, high phase stability and electrical uniformity of its weatherproof Foamflex feed line assemblies. Special connectors, designed and fabricated by Phelps Dodge, link the Foamflex lines to double-tuned, strip-line, four-way power dividers in each quadrant element of the antenna.

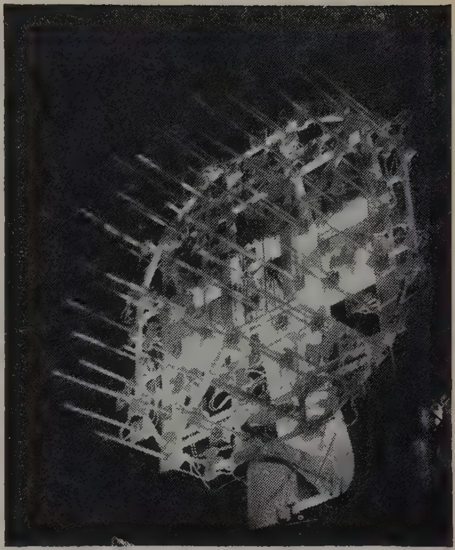
Designed for Edwards Air Force Base, this modular array is assembled from identical quadrants, each equipped with power dividers, dipole antennas and cigar elements. In contrast to the heavier, fixed-type paraboloids, the lighter, smaller Avien-Bogner model costs less, yet has high acquisition capability for telemetry information through the use of three matic tracking modes. Quadrant elements may be replaced when changes are desired in freq bands, due to the simple design and construct this antenna.

The feed system was planned, fabricated, brated and installed by A-T Electronics, Haven, Conn. Accurate uniformity of elec length for each cable was maintained from ca cable within one degree at 2200 megacycles bending.

The outstanding qualities of semi-flexible, a num-sheathed Foamflex have been proved number of applications where low loss, long ating life and a low noise to high signal level are essential. If your specifications call for a c cable of the highest efficiency, we recommend investigate the capabilities of Foamflex.



Center element unit is connected to the junction box of the Avien-Bogner antenna.



Self-tracking Avien-Bogner acquisition array has capability to telemeter data from vehicles traveling in the far reaches of space.

PHELPS DODGE COPPER PRODUCTS
CORPORATION
300 Park Avenue, New York 22, N.Y.

Circle Reader Service Card 31

isolator

ferrite coaxial

and stripline

devices from

250 mc to 12.4 GC

4-port circulator

■ These low frequency devices feature compact design, for higher packing densities. With coaxial, stripline and waveguide devices, Ferrotec offers continuous coverage from 250 mc to 75 GC.

Ferrotec low frequency ferrite components

Component	Frequency Range	Application
T- & Y-Circulators	250mc-10GC	Masers and Parametric Amplifiers, Duplexing
Resonance Isolators	750mc-8GC	Countermeasures — three units give octave bandwidths from 1GC to 8GC
Phase Shifters	1GC-8GC	Antenna Arrays, Frequency Modulators, Electronic Scanners
Switches (Y-Circulators)	1GC-10GC	Antenna Array Scanning — Time Sharing Antennas
Modulators — (Isolators Y-Circulators)	750mc-10GC	Variable attenuators, to modulate CW signals, Radiometry.

Development now in progress to extend the upper limits of these devices to 16GC and higher frequencies.

FERROTEC INC.
217 CALIFORNIA STREET • NEWTON 58, MASS.
Design • Development • Production
of microwave ferrite components

Circle Reader Service Card 32

Industry News

(Continued from page 42)

PRICE AND ENGELDER JOIN EMTECH

Two additions to its senior staff hav been announced by Electromagnet Technology Corp., Palo Alto, Cal. Ve non G. Price has joined the staff manager of Components, and Paul C Engelder has joined as manager of Sy tems.

Mr. Price has been assigned respons bility for guiding EMTECH activities i the area of radio frequency componen development. Initial activities will ce ter on high power microwave filter measurement devices and techniques fo the control of radio frequency interfe ence.

Mr. Engelder will direct EMTEC systems activities in defining and spec fying applications of electromagnet technology to industrial and military i strumentation, measurement, communic tion and control problems.

Mr. Price received his BS and MS de grees from the University of Utah, whi Mr. Engelder is a graduate of the Cal fornia Institute of Technology.

— m w j —

FREQUENCY STANDARDS BECOMES FREQUENCY ENGINEERING LABORATORIES

W. D. Hurley, general manager Frequency Standards, Asbury Park, N. has announced a change in the co pany's name to Frequency Engineerin Laboratories.

Since its formation in 1948, Frequen Engineering Laboratories has been e gaged in the development of precisi wavemeters, microwave filters, caviti and special test equipment for radar a communications systems. In recent yea the company has been engaged in t development and manufacture of sign sources, antennas, transmitters and ceivers, radar beacons, and a variety special test and checkout equipment.

Since Hurley became General Manag of Frequency Engineering Laborator in November, 1960, the company has creased its staff to approximately 1 employees and raised sales to an annu rate of $1.5 million.

— m w j —

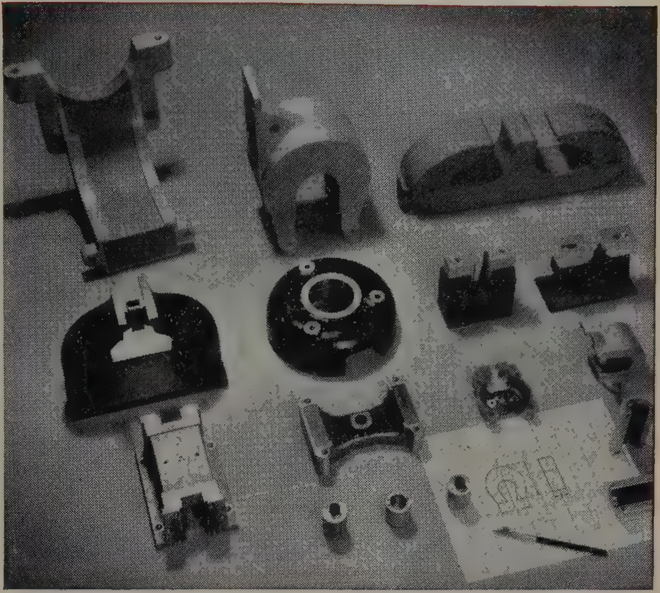
JERROLD NAMES BEISSWENGER AND SPANIER GENERAL MANAGERS

Reorganization of Jerrold Electron Corp., Philadelphia, Pa., has been nounced with appointments of gene managers for its two major operati companies. Sidney Harman, Jerrold pr ident, named Robert H. Beisswenger g eral manager of Jerrold-Philadelphia a Donald Spanier general manager Harman-Kardon.

(Continued on page 48)

Specify "ARNOLD" for your PERMANENT MAGNET requirements

Typical group of Arnold permanent magnets, both cast and sintered types.


Typical group of permanent magnet assemblies, aluminum jacketed.

ALNICO MAGNETS

Arnold permanent magnets are available in all types f Alnico material, in sizes ranging from large castings veighing over 80 pounds to very small sintered parts veighing less than one gram.

Alnico V can usually be depended upon to deliver the reatest energy product to the magnetic circuit per unit veight of magnet material. It is therefore generally the rst choice for a magnetic material except where special hysical considerations are paramount.

Special assemblies such as rotors, traveling wave tube nagnets, magnetron magnets, etc. may be supplied in an luminum jacket to facilitate mounting and supply an dded protection to the magnet.

Large magnet assemblies may also be supplied for mass pectrometer and other measuring applications where a high degree of stability and uniformity of field is required.

Many sizes and types of Alnico magnets are carried in stock for immediate delivery. For more information, *write for Bulletin GC-106C.*

ALNICO VIII

Available from Arnold in production quantities, Alnico VIII possesses the highest coercive force of all Alnico grades, as well as a high energy product and a relatively low temperature coefficient. It is especially suited for traveling wave tube focusing applications. Gap flux densities as high as 1000 gausses are attainable in tubular-type straight field focusing magnets. Alnico VIII is also recommended for applications which involve strong demagnetizing fields, or where space considerations dictate the use of a short magnet. *Write for Bulletin PM-119.*

SPECIAL PERMANENT MAGNET MATERIALS

ARNOX III

Arnox III is a molded-type magnet having high coerive force and moderately low residual induction and nergy product. Principal uses are for magnetic requirenents which are not stringent, and for a relatively short nagnet of reasonable cross section. Accurate dimensions nd close tolerances can be economically obtained. These nagnets can be premagnetized before assembly, and have ery high resistance to demagnetization. Slightly better nagnetic properties are obtained in the pressing direction han in other directions.

ARNOX V

Arnox V is a ceramic permanent magnet material comosed of highly oriented barium ferrite. It has many times he energy product of Arnox III and is comparable in nany applications to Alnico V. Because of its high coerive force, its use is recommended in applications where short magnetic length is desirable, or where extremely igh demagnetizing forces may be encountered.

VICALLOY

Vicalloy is a carbon-free permanent magnet alloy containing about 10% vanadium, 50% cobalt and the balance iron.

Vicalloy may be fabricated in the form of castings, hot rolled bars and forgings, or cold rolled strip, wire and tubing. After suitable heat treatment, the material is quite readily machinable. Vicalloy is available on special order in bar, strip and thin tape for recording purposes.

For more complete information, *write for your copy of "The Magneteer," Vol. 2, No. 1.*

7806-B

AL ARNOLD

ARNOLD

SPECIALISTS in MAGNETIC MATERIALS

THE ARNOLD ENGINEERING COMPANY, Main Office: MARENGO, ILL.
BRANCH OFFICES and REPRESENTATIVES in PRINCIPAL CITIES

MICROWAVE MANAGER

This ferrite phase differential circulator is an Airtron device for managing microwaves in X-band. It was specifically designed to meet the requirements of very high power systems operating at 2 megawatts of peak power and 1500 watts of average power over a frequency band of 8500 to 9600 Mc/s while pressurized at 3 atmospheres. Used as a duplexer, with its fourth arm terminated in a dummy load, this water cooled unit provides 20 db isolation between channels. Others are available for Ka through S bands in both aluminum and brass constructions.

With modifications, these ferrite circulators have been used as diplexers, discriminators, isolators, and switches. Let us work with you, or quote, on the specific configuration for *your* application. Or, write for additional information.

AIRTRON
A DIVISION OF LITTON INDUSTRIES

AIRTRON-MORRIS PLAINS • 200 EAST HANOVER AVENUE, MORRIS PLAINS, N.J.
GENERAL OFFICES AND ADVANCED DEVICES LABORATORIES, MORRIS PLAINS, N.J.

Circle Reader Service Card 34

Industry News

(*Continued from page 46*)

In his new position as chief admini tration officer of the Jerrold group, M Beisswenger will direct Jerrold's produ tion and sales divisions in Philadelphi Mr. Spanier will oversee all operatio of the Harman-Kardon group at the co pany's plant and offices in Plainvie Long Island, N.Y.

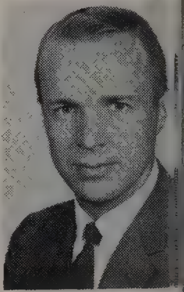
Mr. Beisswenger, who was gener sales manager at Jerrold, was forme vice president and general sales manag of Whitney Blake Company, New H ven, Conn., and sales manager of I diana Steel and Wire Company, Munc Ind. Mr. Beisswenger received his BS degree from Temple University.

Prior to joining Harman-Kardon, M Spanier was general manager of Polaro of Japan, Inc. Mr. Spanier also serv as management consultant to the gover ment of Puerto Rico in connection wi the industrialization program, and foun ed and served as president of the Puer Rico Branch of the Society for the A vancement of Management.

Upon completing his engineering ed cation at the Massachusetts Institute Technology, Mr. Spanier was connect with Continental Can Co. and the ma agement consulting firm of Barringt Associates.

—mwj—

PERRY APPOINTED DIRECTOR O SYLVANIA'S ELECTRONIC DEFENSE LABORATORIES



The appointment of Dr. William Perry as director of Sylvania Elect Products Inc.'s Electronic Defense Laboratories (EDL), Mountain View, Cal., has been announced by Jesse R. Lien, general manager of the Laboratory Operations.

Dr. Perry previously was manager of the Advanced Systems Laboratory within ED EDL is engaged principally in qui reaction research, development and fa rication of various electronic warfa equipment for the U.S. Army Sig Corps, as well as for other governmen agencies.

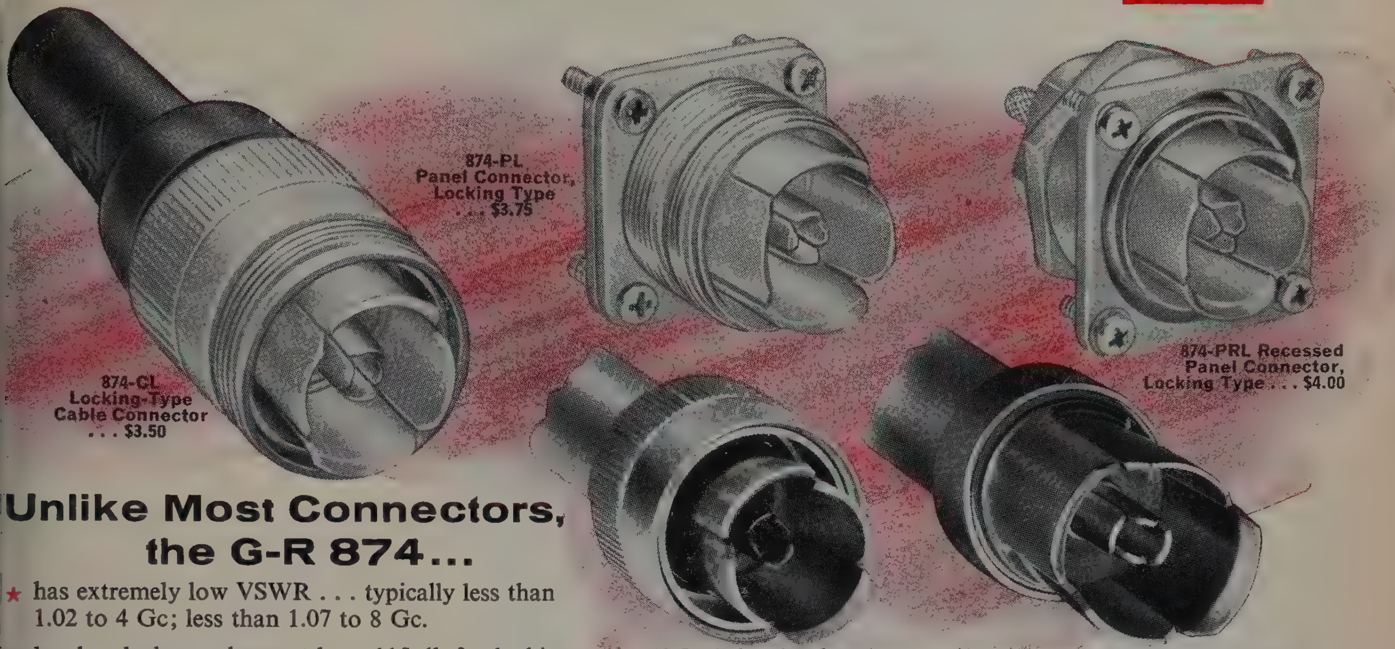
Dr. Perry joined Sylvania in 1954 a served as engineer in charge of ED systems studies department and sub quently as head of the laborator analysis section. Prior to joining t company, Dr. Perry was a systems en neer with Boeing Aircraft Corp., Seatt Wash. and a project engineer with H ler, Raymond and Brown, Inc., Univ sity Park, Pa.

—mwj—

(*Continued on page 50*)

NEW LOCKING CONNECTORS

with Outstanding Characteristics from DC to 8000 Mc



874-PL Panel Connector, Locking Type . . . $3.75

874-PRL Recessed Panel Connector, Locking Type . . . $4.00

874-CL Locking-Type Cable Connector . . . $3.50

874-BL Basic Locking Connector . . . $2.50
for rigid air lines

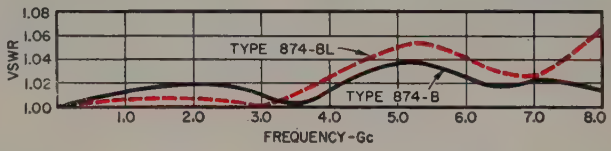
874-B Basic Connector (Nonlocking) . . . $1.60

Nonlocking Cable and Panel Connectors also available

Unlike Most Connectors, the G-R 874...

- ★ has extremely low VSWR . . . typically less than 1.02 to 4 Gc; less than 1.07 to 8 Gc.
- ★ has low leakage; down at least 115 db for locking types at frequencies to 7 Gc.
- ★ is available in locking or non-locking types for semi-permanent or quick connect-disconnect setups.
- ★ forms a rigid, uniform 50-ohm section when connected; provides strong friction-grip contact through multiple-spring fingers.

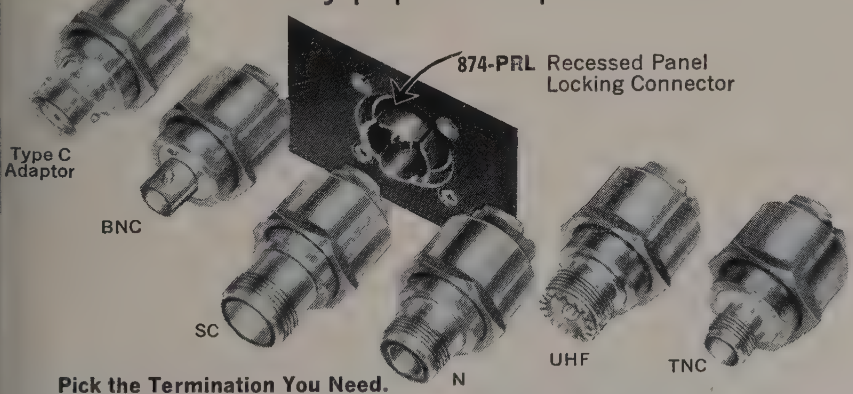
Quantity and O.E.M. Discounts Available.



Any 874 Connector Mates with any other . . . Eliminating continual searches for Male or Female Counterparts.

Put One Panel Connector on all your equipment...

yet conveniently give your customer any popular output connection he wants



Pick the Termination You Need.
Adaptor Prices, $5 to $10. Other types soon to be available.

1"
Protrudes Less than One Inch
Your Product

Adaptor locks into recessed G-R 874 Panel Connector to form low-VSWR connection. Panel Connector is completely hidden. Resulting fitting can be permanent, or readily changed . . . is electrically excellent, trim in appearance.

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS

Please Send Me

☐ Complete specifications for the 874 Coaxial Connector.

☐ Engineering Papers: (1) Methods for high precision measurement of VSWR of coaxial connectors (2) Design techniques for improvement of connector VSWR and repeatability of characteristics (3) RF leakage characteristics of popular coaxial cables and connectors, 500 Mc to 7.5 Gc.

NAME__________ TITLE__________

COMPANY__________

DEPT. OR DIVISION__________ Room, Bldg., Code or Mail Station__________

STREET ADDRESS__________

CITY__________ ZONE_____ STATE__________

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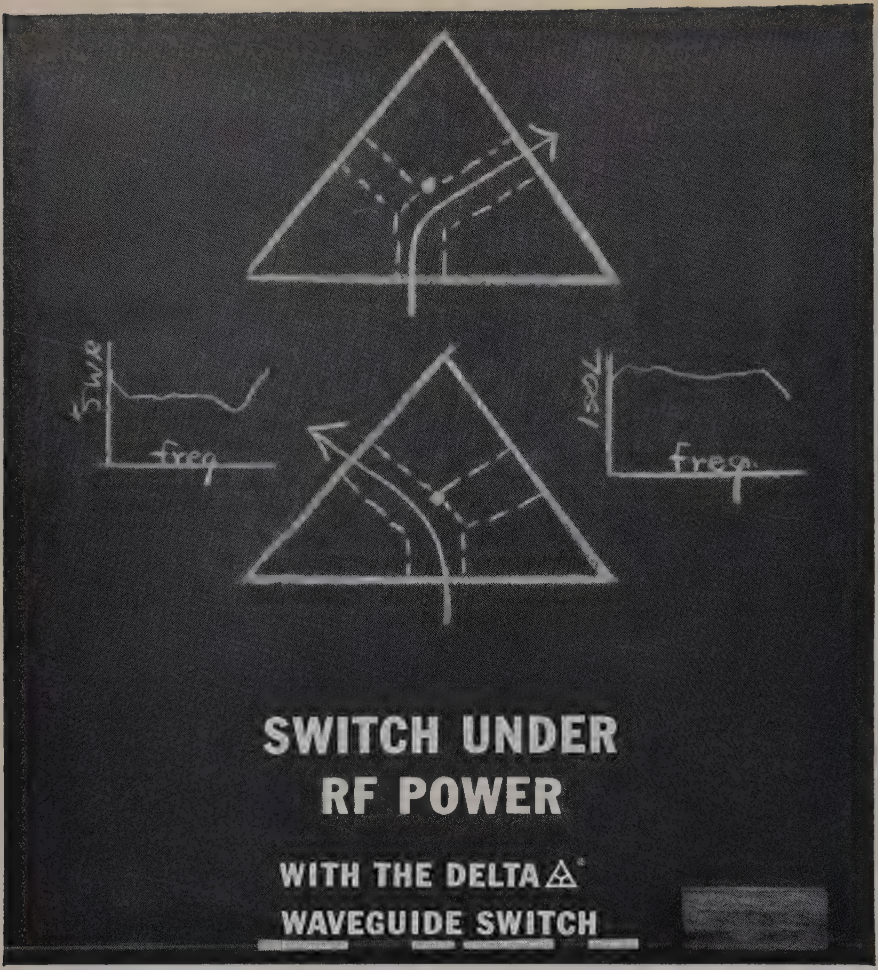


7 milliseconds switching time
7 ounces for x-band model
Operates in severe environments

A new concept in remotely-controlled microwave switching, DELTA ⚠ Waveguide Switches permit 7 millisecond switching under rf power. Control circuitry to shut down magnetrons or other power sources may be *eliminated* in many systems. Switching under rf power is possible because the switching element is a thin metal vane which acts as a power divider during the switching cycle. The benefits—LIGHT WEIGHT, RELIABLE OPERATION and MINIMUM ACTUATOR POWER.

The DELTA ⚠ W-6XA shown here is one of a complete line of rugged waveguide switches designed for reliable operation in critical environments. Write or call us or your Don-Lan Engineering Representative for complete specifications on these switches today.

actual size
(x-band)

*PATENT PENDING

Don-Lan Electronics, Inc.
a subsidiary of
Quantatron, Inc.
1131 Olympic Blvd.
Santa Monica, California
EX 3-0758

Don-Lan specializes in combining optimum microwave and electro-mechanical techniques.
Consult us on your microwave electronic problems.

Industry News

(*Continued from page 48*)

ROSEN APPOINTED GENERAL MANAGER OF POLARAD'S EQUIPMENT ENGINEERING DEPT

The appointment of Bernard Rosen t the position of general manager, Equipment Engineering, has been announced by Frank Skwarek, vice-president of the Defense Products Division of Polarad Electronics Corp., L.I., N.Y.

Mr. Rosen will direct an engineering and pilot production group with the responsibility of developing new designed prototypes for production pra ticability. Mr. Rosen joined Polara Electronics in 1951. He received h BEE from the City College of New Yor and his MEE from Brooklyn Polytechni Institute.

He is a member of the IRE and serve on the Professional Groups on Antenna and Propagation, Microwave Theory an Techniques, and Radio Frequency Inte ference.

— *mwj* —

WILCOX ELECTRIC, HOFFMAN ELECTRONICS COMBINE EFFORTS ON DME EQUIPMENT

Wilcox Electric Co., Inc., Kansas Cit Missouri, and Hoffman Electronics Corp Los Angeles, Cal., have announced a agreement under which a new aircra DME (Distance Measuring Equipmen package will be engineered, produce and marketed.

The DME is an electronic navigatio device which shows a pilot his actu distance from a fixed ground beacon i nautical miles. Designated the Wilco 833 DME, it is a system comprised of transmitter-receiver, instrument pan indicators and control unit, antenna, an associated hookup gear.

While Hoffman Electronics Corp. ha been responsible for the initial desig effort of the Wilcox 833 DME, compl tion of the prototype equipments will b a joint Wilcox-Hoffman engineering pr ject.

— *mwj* —

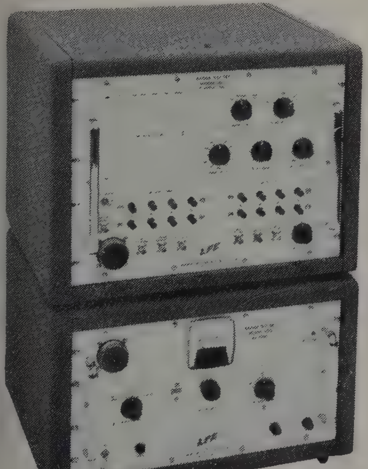
(*Continued on page 54*)

COMPATIBLE INSTRUMENTATION FOR MTI RADARS

by JOHN N. CULLEN
Director, Instrument Division
LABORATORY FOR ELECTRONICS, INC.

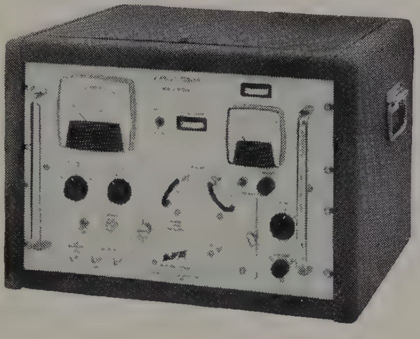
During the past several months, we have discussed on this page various measurement problems in the microwave field, and suggested how these problems may be solved. Four of the instruments previously described are applicable to the MTI measurement problem. To emphasize that these four instruments as a group are particularly compatible in MTI radar testing and maintenance, their principal specifications are summarized below.

Since the ability to detect moving targets in a clutter of fixed targets is the primary measure of an MTI radar's usefulness, an instrument to measure SCV (subclutter visibility) directly is most useful — in the laboratory during design, in final test, or in the field to maintain peak performance. In September* we described the Model 5012 MTI Radar Test Set and its use, a set which measures SCV directly in db with a minimum number of disconnections and at minimum inconvenience. Not only can this measurement be made in a shorter time than by any other method, but the set also isolates oscillator instabilities, timing instabilities, and other malfunctions to one or more system components, and yields a direct measure of SCV at r-f (L-, S-, C-, or X-band), i-f & local i-f (30 or 60 mc/s), and video levels.



Model 5012 Radar Test Set

As pointed out in March*, the first local oscillator of an MTI radar must be stable to a few cycles per second. At that time we described the Model 5024 Stability Tester which is capable of measuring both long-term instability (drift) and short-term instability (residual f-m), the latter to 0.3 cps at L band, 0.5 cps at S band, 0.7 cps at C band, 1.5 cps at X band, and 2 cps at K_u band over a narrow band of frequencies. Both long- and short-term instability measurements are direct meter displays, the first in kc/s, the second in cps. Therefore if the Model 5012 isolates MTI malfunction to the stabilized local oscillator, the 5024 is the appropriate instrument to see the effect of corrective measures immediately. The 5024 is also invaluable during the design of such oscillators.

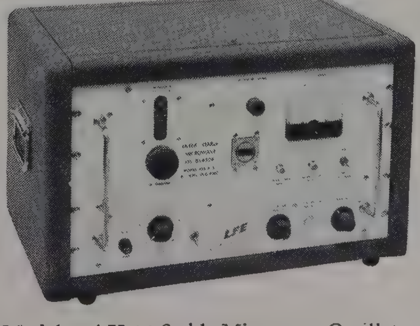


Model 5024 Microwave Stability Tester

> And for those who don't relish the miserable problem of designing stabilized microwave oscillators, LFE produces a line of ultra-stable microwave oscillators from 2 to 25 Gc. The 814-Series Tunable Oscillators, described in May* and January*, have a long-term stability of one part in 10^6, and a short-term stability of five parts in 10^8. In addition to the tunable 814-Series as well as the fixed-tuned 820-Series models, LFE makes packaging and engineering modifications to meet particular systems requirements.

In addition to frequency instabilities — stalo, coho, and magnetron — the 5012 can isolate malfunctions caused by timing instabilities. After isolation, the Model 5015 Time Stability Tester discussed in February* is extremely useful for further analysis of such malfunctions.

The 5015 linearly converts time variations to voltage variations for meter display of jitter level, provides for scope display of the disturbance waveform, accommodates pulse-repetition rates from 50 to 50,000 pps, and accommodates time spacings between reference pulse and measured pulse from zero to thousands of microseconds (the upper limit depending on the PRF). The 5015 measures time jitter up to one microsecond peak with residual jitter (internal noise) below 0.5 nanoseconds. Meter ranges are 3, 10, 30, 100, 300, and 1000 nanoseconds peak.



Model 814-X-21 Stable Microwave Oscillator

The measurement of time always implies a reference, and the practical problem of jitter measurement leads to three types of time jitter which correspond to the three different sources of time reference:

1. *Pulse-width jitter,* where the leading edge is the reference for the measurement of jitter on the trailing edge;
2. *Relative jitter,* where the leading edge from a second source is the reference for the leading edge of the first source, such as between a generated pulse and its trigger; and
3. *PRF jitter,* the time jitter of the leading edges of pulses in a train relative to the pulses in a highly stable second train which is generated internally by a variable crystal oscillator.

The Model 5015 handles all three. In fact, it can measure PRF jitter on a sine-wave as well as a pulse-train input. Hence instability of a PRF pulse train can be checked back to its sine-wave source, if it has one.

Model 5015 Time Stability Tester

If you would like reprints of the prior technical discussions of these instruments (which have other uses than as compatible MTI test equipment), descriptive bulletins, or answers to particular questions, write Mr. Perry Pollins at the address below.

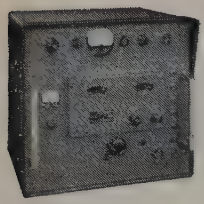
LABORATORY FOR ELECTRONICS, INC.
714 Beacon Street, Boston

**Although some of these discussions have appeared in other publications, reference herein to months is to 1961 issues of the Microwave Journal which has carried them all.*

Circle Reader Service Card 37

ONLY A POLARAD MICROWAVE
THROUGH 4,200 to 11,000 mc

Which Polarad Generator Solves Your Problem?—500 to 50,000 mc



Model PMR

500 to 1,000 mc

Interchangeable FM or pulse modulators. FM modulator provides low distortion wide-range, sine-wave deviation. Pulse modulator provides pulse, square wave and saw-tooth FM. (10-10,000 pps). Calibrated power output: 1 mw

All Polarad Signal Generators (500 to 21,000 mc) offer:

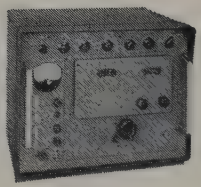
Continuously variable attenuators calibrated directly in —dbm.

Internal pulse, FM and square wave modulation, external pulse and multi-pulse modulation.

Delayed and undelayed sync outputs.

UNI-DIAL® tuning with direct-reading frequency dials accurate to ± 1%.

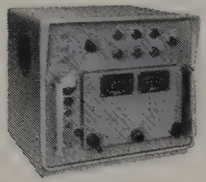
High stability non-contacting klystron cavity chokes for noiseless tuning and accurate calibration.



Model MSG **950 to 4,600 mc**

	Frequency	Calibrated Power Output	Internal Pulse Modulation					
			Internal Square Wave	Width in μ sec.	Pulse Repetition Rate in pps	Delay in μ sec.	FM deviation in mc minimum
MSG-1	950-2,400 mc	1 mw (0 dbm)	40- 4,000 pps	0.5-10	40- 4,000	2.5-300	±2.5
MSG-1P*	950-2,400 mc	10 mw (+10 dbm)	10-10,000 pps	0.3-10	10-10,000	2-2,000	±2.5
MSG-1R	950-2,400 mc	1 mw (0 dbm)	10-10,000 pps	0.3-10	10-10,000	2-2,000	±2.5
MSG-2A	2,000-4,600 mc	1 mw (0 dbm)	40- 4,000 pps	0.5-10	40- 4,000	2.5-300	±2.5
MSG-2R	2,000-4,600 mc	1 mw (0 dbm)	10-10,000 pps	0.3-10	10-10,000	2-2,000	±2.5
MSG-2P*	2,000-4,600 mc	10 mw (+10 dbm)	10-10,000 pps	0.3-10	10-10,000	2-2,000	±2.5

*Attenuator Accuracy: ±3 db between 0 and +10 dbm.
±2 db below 0 dbm.

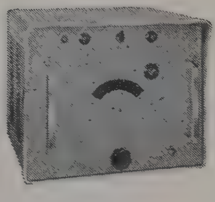


Model PMX

4,450 to 8,000 mc
6,950 to 11,000 mc

Two interchangeable r-f generator units.

Internal pulse and square wave modulation (10-10,000 pps); 0 to —127 dbm power output.



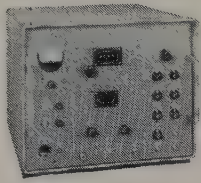
Model KSS

GENERATOR SOURCE

1,050 to 11,000 mc

in 4 tuning units

Power output: 14 to 400 mw, depending upon frequency; internal square wave 10-10,000 pps; external pulse, square wave or FM modulation; adjustable attenuator.

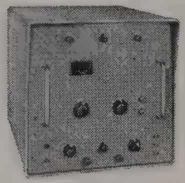


Model MSG-34

4,200 to 11,000 mc

in one instrument

Internal pulse and square wave modulation (10-10,000 pps); 0 to —127 dbm power output; DIGITAL frequency indicator.



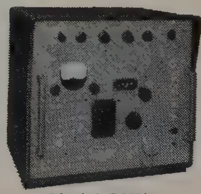
Model CSG

SWEEP GENERATOR

1,000 to 16,000 mc

in 5 interchangeable tuning units

Provides high-power microwave signal adjustable from single frequency to 2:1 frequency range; .001 to 100 cps sweep rate; internal modulation: 1,000 cps and 456 kc square wave; external modulation: square wave, FM and pulse.



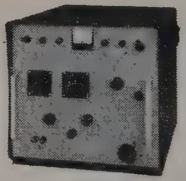
Model PMK

10,000 to 21,000 mc

in 2 tuning units

Two interchangeable generator units.

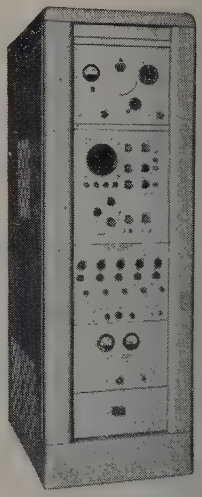
Calibrated power output: + 10 dbm (10 mw); internal pulse and square wave modulation (10-10,000 pps); DIGITAL frequency indicator.



EHF SIGNAL GENERATOR AND SOURCE

12,400 to 50,000 mc

Units in this range provide cw signals, 1,000 cps internal square wave, external modulation provisions, accurate frequency calibration. EHF SIGNAL GENERATOR 18,000 to 39,700 mc, 7 plug-in units. Accurate power calibration. EHF SIGNAL SOURCE 18,000 to 50,000 mc, 9 plug-in units. High power output.



Model B

CODE MODULATOR MULTI-PULSE GENERATOR

950 to 10,750 mc

in 4 interchangeable tuning units.

Provides 5 independently adjustable pulse channels, each with variable pulse width and delay. Built-in precision oscilloscope.

Because each of these fine test instruments has something special about it, a feature or capability that can suit your test requirements exactly, check through this ad—then get complete specifications from your local Polarad representative.

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ELECTRONICS CORPORATION

43-20 34TH STREET, LONG ISLAND CITY 1, NEW YORK

FREE LIFETIME
SERVICE

SIGNAL GENERATOR CAN TUNE WITH ONE CONTROL

This Polarad patented* tuning cam is one of the many ingenious devices that make possible continuous tuning from 4,200 to 11,000 mc in the Polarad Model MSG-34 Signal Generator.

*(U.S. Patent No. 2,824,466)

Model MSG-34 Because of its unique electromechanical design, only the MSG-34 Microwave Signal Generator offers such a wide frequency range in one unit—with 1 mw calibrated power output from 4,200 mc to 11,000 mc.

The printed circuit modulator is important, too. A single unit offers 10 to 10,000 cps rates for pulse, FM and square wave rf outputs. All with the shortest pulse width available—0.2μ sec.

SPECIFICATIONS

Frequency Range	4,200 mc to 11,000 mc
Frequency Accuracy	±1%
Power Output	1 milliwatt (0 dbm) calibrated
Attenuator Output Accuracy	±2 db from 0 to −127 dbm
Modulation	Internal or external pulse, square wave or internal FM

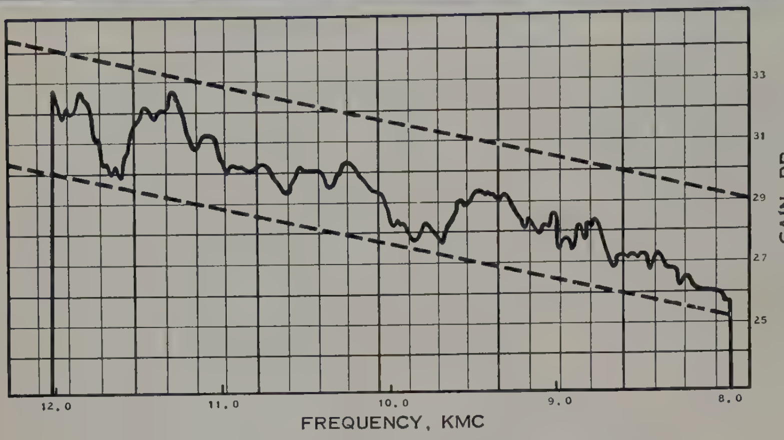
Internal Pulse Modulation:

Width	0.2 to 10 microseconds
Repetition Rate	10 to 10,000 pps
Delay	2 to 2,000 microseconds

POLARAD

Circle Reader Service Card 38

SLOPE GAIN TWT FOR IMPROVED SYSTEM OPERATION



RECORDED PLOT OF SMALL SIGNAL GAIN VS FREQUENCY OF A MODIFIED HUGGINS HA–20 PM FOCUSED TWT AMPLIFIER

The production department at Huggins Laboratories has become very adept at providing traveling wave tubes having specific performance characteristics. These characteristics generally have stressed achievement of a prescribed small signal gain as a function of frequency over definite frequency bands, depending on customer requirements.

As an example, tubes can be provided in which small signal gain varies at some prescribed rate as a function of frequency. The use of a TWT whose gain increases as frequency increases makes it possible to compensate for losses of other microwave system components, which generally increase with frequency, also. The over-all result is a system which, between two given points, has a response which is very nearly independent of frequency. Traveling wave tubes having such properties have been supplied over several specific frequency ranges within the 2.0 to 12.4 KMC bands.

The curve above gives an example of the extent to which the small signal gain response of a TWT amplifier may be controlled. Here, the modification of a standard X-band PM-focused amplifier resulted in an average gain which increased by 1.5 db per 1000 MC increase in frequency over the 8.0 to 12.0 KMC band. Response of this type is possible with no adjustment necessary by the user external to the tube — the curve is presented with all potentials and currents fixed. Other types of gain responses are also possible, such as TWT amplifiers whose gain varies at some fixed rate over certain particular frequency bands.

The curve is a plot made with a pen recorder used in conjunction with a constant power system. This system makes use of a gridded low-level TWT and the use of feedback to control its output such that it is very nearly constant as a function of frequency and drive (over certain input level ranges). Such a system is described in Huggins Engineering Note, Number 8, *"The use of the TWT in constant power systems."*

A copy of this is available upon your request, and is bound in our two-volume catalog set which is also available should you not already be on our mailing list. Submit inquiry on company letterhead.

HUGGINS LABORATORIES, INC.

HUGGINS LABORATORIES
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development
engineering
design
research

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Circle Reader Service Card 39

Industry News

(*Continued from page 50*)

HAYSTACK ANTENNA SYSTEM TEST PANEL BONDED

Bonding of an aluminum honeycomb test panel for the 120-foot Haystack antenna system was recently completed at the Columbus Division of North American Aviation, Inc., Columbus, Ohio.

Ninety-six of the one-half inch thick aluminum honeycomb panels will be required to form the 120-foot reflector of the research instrument being built for the U.S. Air Force.

Haystack, which will be used for global communications and space studies, will be erected inside a 150-foot protective radome atop Haystack Hill at Tyngsboro, Mass., about 25 miles northwest of Boston. It is scheduled to go on the air in late 1962.

The seven-acre surface of the reflector will never vary more than one-thirteenth of an inch. Needle-sharp beaming ability will permit the antenna system to detect a one-quarter inch steel sphere at a range of 1000 miles.

— *m w j* —

S-F-D NAMES GARRAHAN PLANT ENGINEER

Philip G. Garrahan has been appointed plant engineer of S-F-D laboratories, Inc., Union, N.J.

Mr. Garrahan will be responsible for plant construction, maintenance and services. He will continue to supervise the design and construction of the company's mechanical equipment development activity.

Mr. Garrahan joined S-F-D in 1959. He holds BS and MS degrees in mechanical engineering from Newark College of Engineering.

— *m w j* —

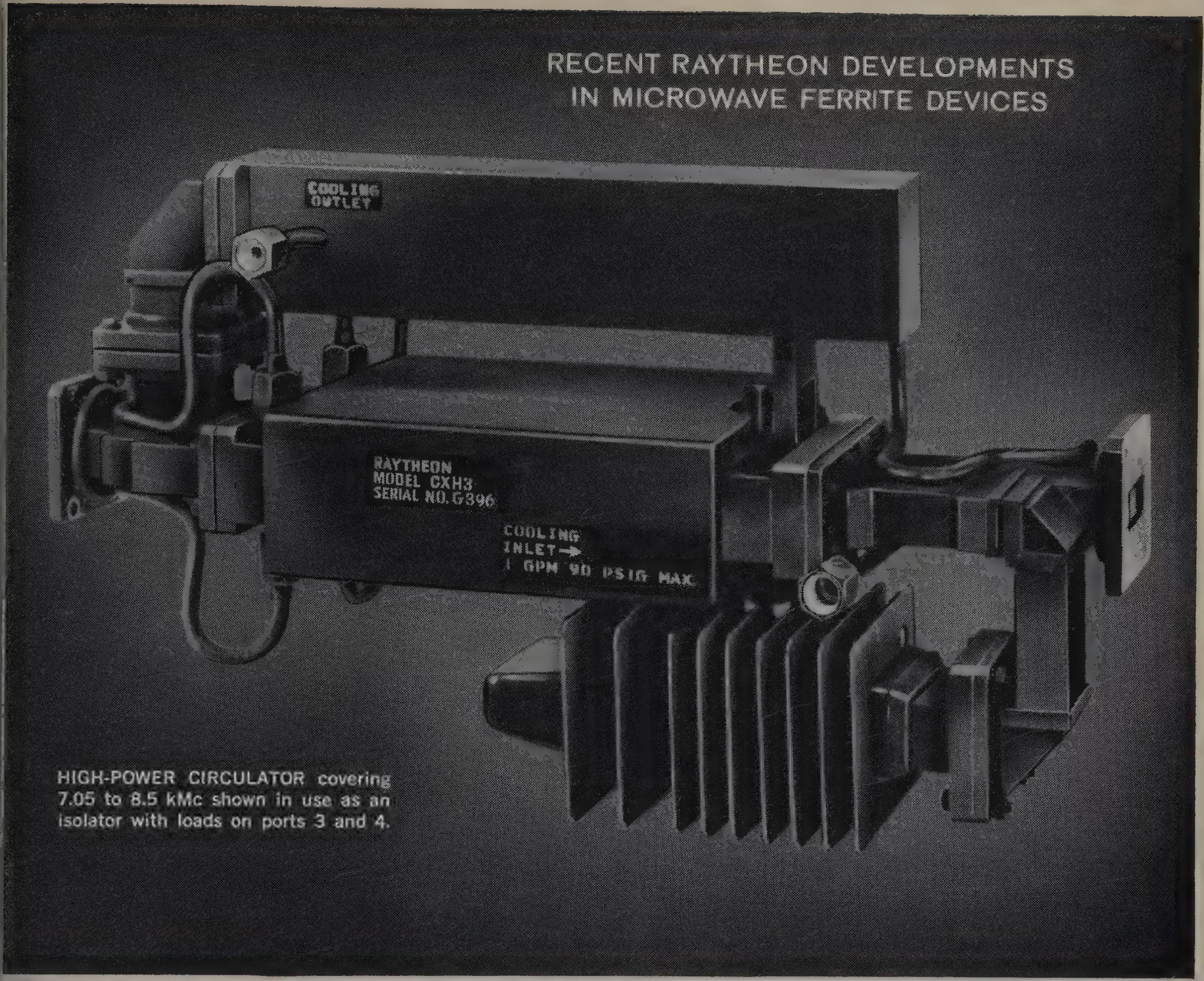
MANAGEMENT STAFF EXPANDED AT STEWART ENGINEERING

Stewart Engineering, Santa Cruz, Cal., has recently created two new management posts. Ray Stewart, president of the firm, announced the appointment of Gerald C. Rich as general manager, and Milton J. McNeal as manager of Manufacturing.

Prior to his new assignment at Stewart, Rich was manager, Engineering Operations, at the Sylvania Reconnaissance Systems Laboratory in Mountain View, Cal. Previous to that he held managerial positions in Sylvania's Microwave Tube and Electronic Defense Laboratories, and with Motorola, Inc., Phoenix, Ariz.

Rich, an electrical engineering graduate of Massachusetts Institute of Technology, is a member of the American

(*Continued on page 57*)


RECENT RAYTHEON DEVELOPMENTS IN MICROWAVE FERRITE DEVICES

HIGH-POWER CIRCULATOR covering 7.05 to 8.5 kMc shown in use as an isolator with loads on ports 3 and 4.

X-band circulators take 20 kW CW to match state of the art in tubes

New unit tested at 20 kW continuous power; can be used as isolator or duplexer

This high-power CXH3 circulator provides greater than 20 db of isolation over the 7.05 to 8.5 kMc band with a maximum insertion loss of less than 0.3 db. The CXH3—developed under U.S. Army Signal Corps contract number DA-36-039-SC-85372—is typical of circulators Raytheon can supply for any X-band segment at power levels up to 25 kilowatts average and 2 megawatts peak.

Write for technical details on this and other significant developments in high-power microwave ferrite devices to Special Microwave Devices Operation, Raytheon Company, Waltham Industrial Park, Waltham 54, Massachusetts.

TYPICAL SPECIFICATIONS
MODEL CXH3 CIRCULATOR

Frequency Range	7.05-8.5 kMc
Power (CW)	20kW
Isolation	20 db min.
Insertion loss	0.3 db max.
VSWR	1.15 max.
Length	14.5 inches
Flanges	UG 51/U
Waveguide	RG 51/U
Weight: Incl. loads	19 lbs.
Excl. loads	12.5 lbs.
Cooling	1 gpm @ 90 psi max.
Recommended Pressurization	10-15 psig nitrogen or dry air

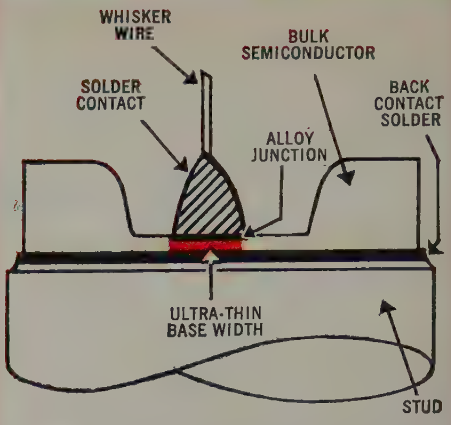
RAYTHEON

RAYTHEON COMPANY

SPECIAL MICROWAVE DEVICES OPERATION

PHILCO ANNOUNCES INDUSTRY'S

FIRST GERMANIUM VARACTORS



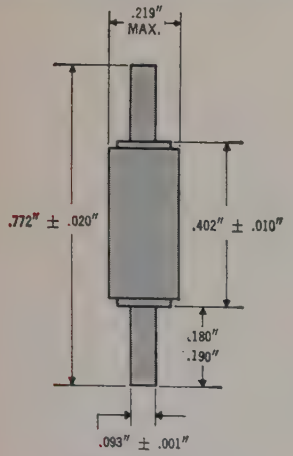
Philco Germanium Microetch construction creates an ultra-thin base width (shown in red). Result: higher breakdown voltage for a given cutoff frequency . . . and greatest capacitance variation.

New Philco varactor types L-4110, L-4111, and L-4112—Industry's first germanium varactors—herald new capabilities for harmonic generators, parametric amplifiers, RF tuning devices, and a wide variety of all-solid state power sources.

Philco Germanium Microetch process, heart of the new varactor capability, combines with the low contact potential inherent in germanium to produce large capacitance variation. And large capacitance variation means more efficient frequency conversion — the capability that makes the varactor ideal for harmonic generators.

Originally designed for Philco's own all-solid state power sources, these varactors now are commercially available for your own designs.

DIMENSIONAL OUTLINE AND MECHANICAL SPECIFICATIONS



OUTSIDE DIMENSIONS

PHILCO GERMANIUM VARACTORS

Parameters	L-4110	L-4111	L-4112
Max. Power Dissipation	0.4 watts	0.3 watts	0.2 watts
Breakdown voltage (minimum at —200 μa)	80 volts	40 volts	20 volts
Junction capacitance (at 100 kc and varactor biased at ⅓ V_b)	1.0-2.0 pf	0.35-0.7 pf	0.17-0.35 pf
Series resistance (typical; measured at 2 Gc and varactor biased at ⅓V_b)	5 ohms	6 ohms	7 ohms
Cutoff frequency (minimum; calculated at ⅓.V_b)	25 Gc	60 Gc	100 Gc
Lead inductance (typical; measured at 2 Gc)	0.4 nhy	0.4 nhy	0.4 nhy
Cartridge capacitance (typical; measured at 100 kc)	0.2 pf	0.2 pf	0.2 pf

For data and applications assistance, write Dept. MJ 1061
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(*Continued from page 54*)

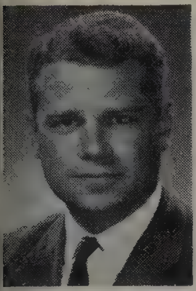
Management Association and the American Physical Society, and is a senior member of the Institute of Radio Engineers.

Milton J. McNeal, Stewart's new production manager, was employed for a number of years by Varian Associates, where he was supervisor of Production Engineering in klystrons, and later, manager of Manufacturing Engineering. McNeal is an honors graduate of San Jose State, with a degree in mechanical engineering. He has patents pending, related to techniques in microwave tube production.

—*mwj*—

TYCO ACQUIRES TRICONIX

The addition of Triconix Inc. to the growing family of TYCO subsidiaries has been announced by Dr. Arthur W. Tyler, president of TYCO, Inc., Waltham, Mass.



PENFIELD

Triconix was formed by Hays Penfield, recently group director at Ewen Knight and, prior to that, staff member of the MIT Lincoln Laboratory. The firm specializes in radiometric receiving systems, phase tracking interferometers, passive navigation equipment, and special rf instrumentation. In addition to component and systems development, Triconix also markets a line of laboratory and space radiometers, low-noise uhf amplifiers, and rf calibration generators.

—*mwj*—

DESIGN AMPLIFIERS ASSURE INCREASED POWER FOR SPACE COMMUNICATION

Advanced design microwave amplifiers now under early tests at the Sperry Electronic Tube Division, Gainesville, Fla., promise a tremendous boost in power, efficiency and message capacity for future space communication systems.

Employing an adaptation of a circuit devised for speeding electrons in atom smashers, Sperry expects to multiply by four times the output of high power amplifiers called klystrons. The circuit also will double a system's message-carrying capacity.

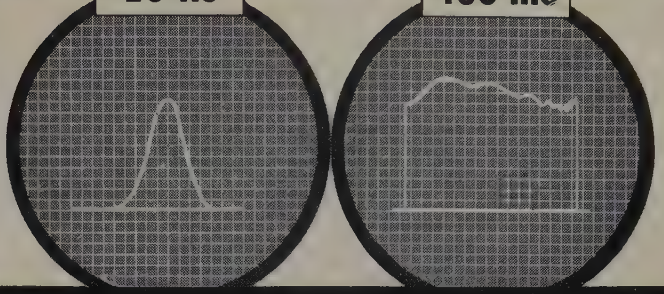
The tubes also are expected to increase the effectiveness of satellite tracking systems or radar astronomy systems mapping stars or the surface of the moon.

Scientists call the amplifiers extended interaction klystrons. They will hike power by accelerating electrons along "standing waves" generated by a series of circuits inside the tubes. These circuits, or resonators, have an effective

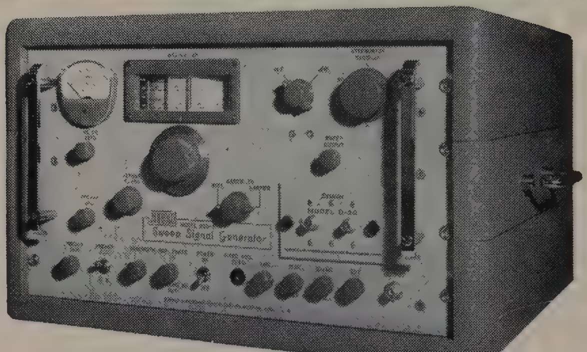
(*Continued on page 68*)

VERY NARROW TO VERY WIDE

10 kc **400 mc**



SWEEP WIDTHS*



...ALL IN ONE INSTRUMENT

NEW JERROLD® 900B

SWEEP SIGNAL GENERATOR

Here's the last word in versatility and precision, the ultimate instrument for all your IF-VHF-UHF requirements. The new Jerrold 900B offers unusual stability in sweep widths as narrow as 10 kc and as wide as 400 mc. Frequency range 500 kc to 1200 mc.

$1980.00 *f.o.b. Philadelphia***

*Illustration of scope at left shows typical communications receiver response 4 kc bandwidth at 7 mc. Illustration at right shows typical distributed amplifier response 2-220 mc.

***Prices and specifications subject to change without notice.*

- **Built-in crystal-controlled harmonic markers at 1, 10, and 100mc intervals.**
- **Each marker output individually controls from front panel.**
- **Built-in variable-gain dc-coupled scope preamplifier with 200X gain.**
- **Built-in precision attenuator from zero to 50db in 10db steps.**
- **Accurately calibrated frequency dial.**
- **High-level metered output.**

Write for complete technical data.

JERROLD® **ELECTRONICS CORPORATION**
Industrial Products Division, Dept. ITE-115
The Jerrold Building, Philadelphia 32, Pa.

Jerrold Electronics (Canada) Ltd., Toronto •
Export Representative: Rocke International, New York 16, N.Y.

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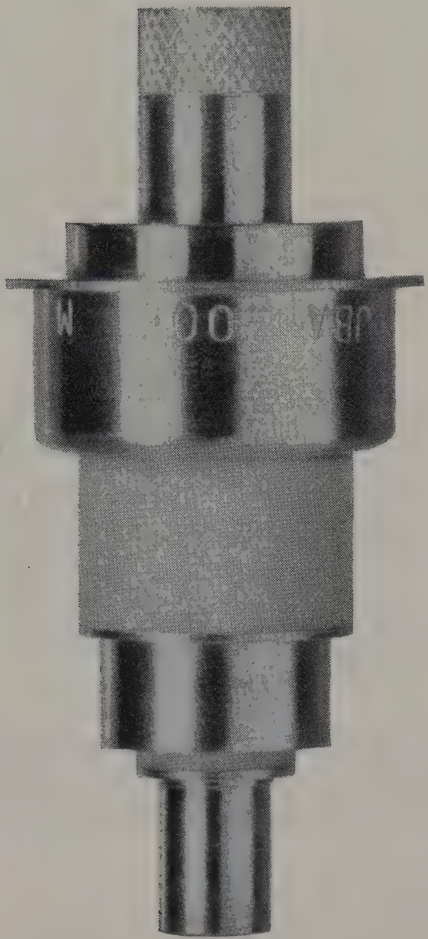

UHF

Grid Modulated

To 2000V Ebb

ML-7815

Ceramic Planar Triode

Grid-modulated to 2000V Ebb, 3.0 a ib, ML-7815 can provide a pulse width of 6 usec at 0.0033 Du. In plate-pulsed service the ML-7815 offers similar ratings to 3500 v eb.

Unusual high voltage stability is assured (for high altitude operation) by the extended, ceramic grid-anode insulator. The new arc-resistant nickel matrix cathode minimizes high-voltag breakdown by a factor several times that of conventional types.

Send for Machlett UHF Planar Tube Brochure

MACHLETT

Subsidiary of Raytheon Company

The Machlett Laboratories, Inc.
Springdale, Connecticut

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APPLIED
MICROWAVE
ELECTRONICS

Applied Microwave Electronics plant in Meadows Industrial Park just outside of Baltimore.

NTRODUCING

APPLIED MICROWAVE ELECTRONICS, INC.

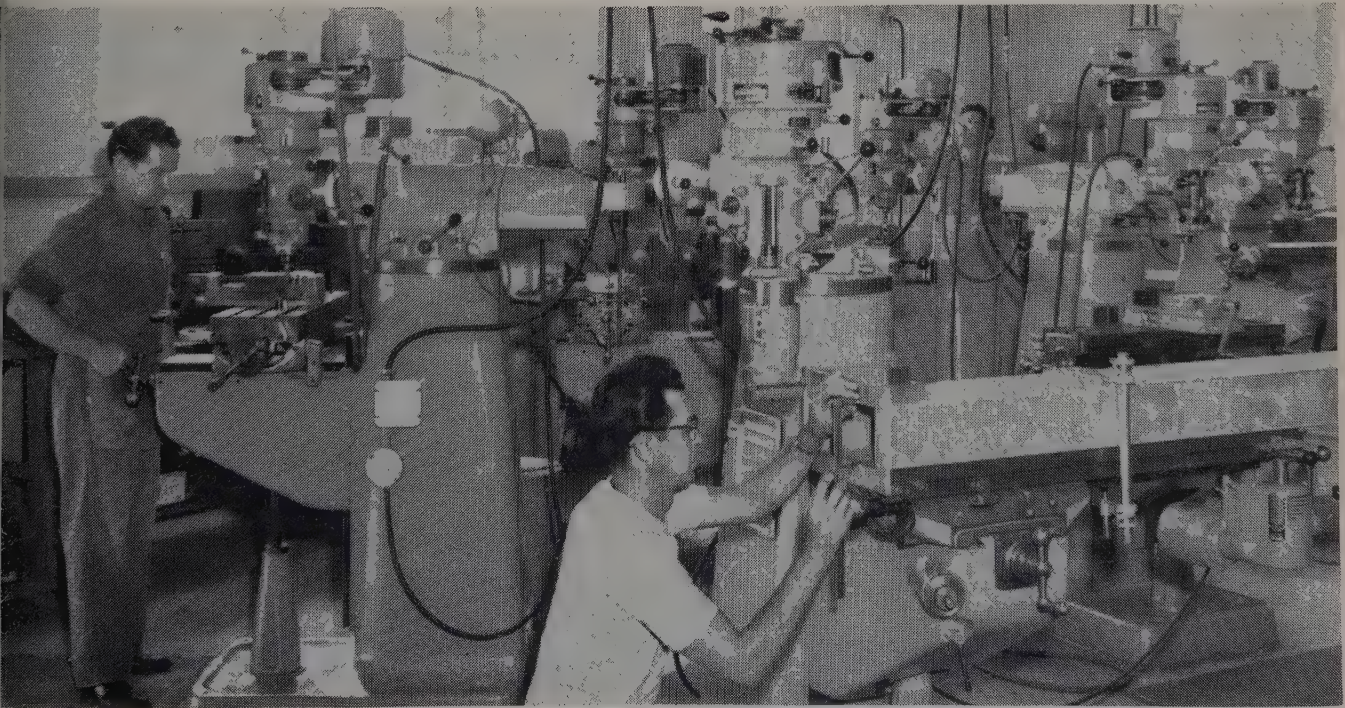
Baltimore, Maryland

"There be three parts to business: the preparation, the debate or examination, and the perfection. Whereof if you look for dispatch, let the middle part only be the work of many and the first and last the work of few." Sir Francis Bacon "ON DISPATCH" (1597)

Applied Microwave Electronics was a year old three months ago. Founded in Baltimore in July 1960, the then-infant company consisted of three people: J. Kelsey Burr, III, president, J. Gordon Neuberth, vice president and chief engineer, and a secretary. Its offices were located in three small rooms on the second floor of a row house converted to business use. As Mr. Burr puts it: "There was just enough room to think in." Total sales for fiscal 1960 were about $34,000. The sales force was Mr. Burr.

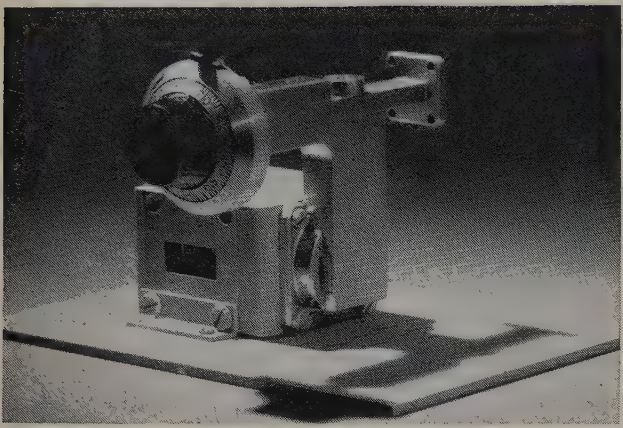
Today, a little over a year later, Applied Microwave is comfortably located in a new 7,000 square foot facility at 6707 Whitestone Road in the Meadows Industrial Park just outside of Baltimore. The building is already crowded to capacity and there are plans underway for expansion to 55,000 square feet. The new facility includes a com-

(*Continued on page 60*)



Face milling a standard WR 975 waveguide termination.

NOW . . . X BAND
NONDEGENERATE
PARAMETRIC AMPLIFIERS
with a tuning range of 1.1 Gc!



Single-knob tuning over a range of 1.1 Gc in the X band is featured in this nondegenerate parametric amplifier by Texas Instruments Incorporated. Bandwidth is 30 mc and gain is 15 db. Noise figure, including circulator loss and normal second stage, is 4.5 db. Its broadband signal frequency response and fixed pump frequency give you dependable operation with a minimum of tuning adjustment.

TYPICAL MODEL X-22 SERIES SPECIFICATIONS

Mode of Operation	Nondegenerate
Tuning Range	8.5 to 9.6 Gc
Bandwidth	30 mc
Gain	15 db
Noise Figure (Including circulator loss and normal second stage)	4.5 db
Pump Frequency	24.0 Gc
Diode	Texas Instruments Gallium Arsenide Diode
Pump Power	50 mw

For more details about this amplifier or other Texas Instruments parametric amplifiers operating at L, S, C, and X bands, contact RADAR AND MICROWAVE PRODUCTS DEPARTMENT.

APPARATUS DIVISION
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APPLIED MICROWAVE

(*Continued from page 59*)

plete and modern machine shop, engineering quarters, an a precise and well-equipped laboratory for testing th company's many designs of high power passive micro wave components. Personnel now number 25, with factory sales force and five manufacturers' representative throughout the East. The company contemplates $650,00 in sales by the end of fiscal 1961.

There have been many "success stories" in the rapid expanding field of electronics. But while Mr. Burr wi not yet admit to success, there is every indication that h and his colleagues have followed pretty closely (wheth knowingly or not) the advice of Francis Bacon . . . an that it is beginning to pay off.

The Preparation

Not only did Applied Microwave start with thre people . . . . it had only those three until late Januar 1961 (although it did employ some part-time consu tants). By February there were only seven and it wasn until April that things really began to move. In Jun the company moved into its new quarters and the person nel complement was immediately increased to almost it present level.

During those first six months, Mr. Burr and Mr. Ne berth covered a lot of ground, but none of it was mor important to them than their planning for the future. O this point, Mr. Burr said, "The strength of any sma new company and its ability to grow and prosper ar almost wholly dependent on the amount of advance planning put into the operation. This planning stag need not be a long one, but it should be a thorough on For it is in this critical stage of the business that th founders can avoid the most common of the many sma company pitfalls . . . . and it is here, too, that they ca take advantage of most of the small company advantages

Among the pitfalls enumerated by the two founders Applied Microwave was that of having the company's fe key men, become so deeply involved in the everyday de tails of engineering, production and delivery schedul that their much needed ability to act and plan objective at this stage is hampered. They also pointed out that suc immersion into detail would tend to reduce manageme personnel to a level below truly management status an would create a contracting rather than an expandin frame of mind.

In speaking of the advantages to be gained by carefu planning, Burr and Neuberth outlined several:

— Objectives can be clearly set and well-defined. flexibility can be built into these objectives that wi allow a small company (such as Applied Microwave) t get the jump on its larger competitors should the need o product opportunity arise.

— Market analysis can be complete and precise. Specia ization areas can be selected and avoided.

— Careful planning can result in a truly balanced pr duct mix. (At Applied Microwave, 40 per cent is pr grammed to standard proprietary items, 25 per cent t R & D, 25 per cent to prime military contracts and 1 per cent to internal development.)

— Good general rules can be established by which

(*Continued on page 62*)

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From the Indiana Steel Products Division of
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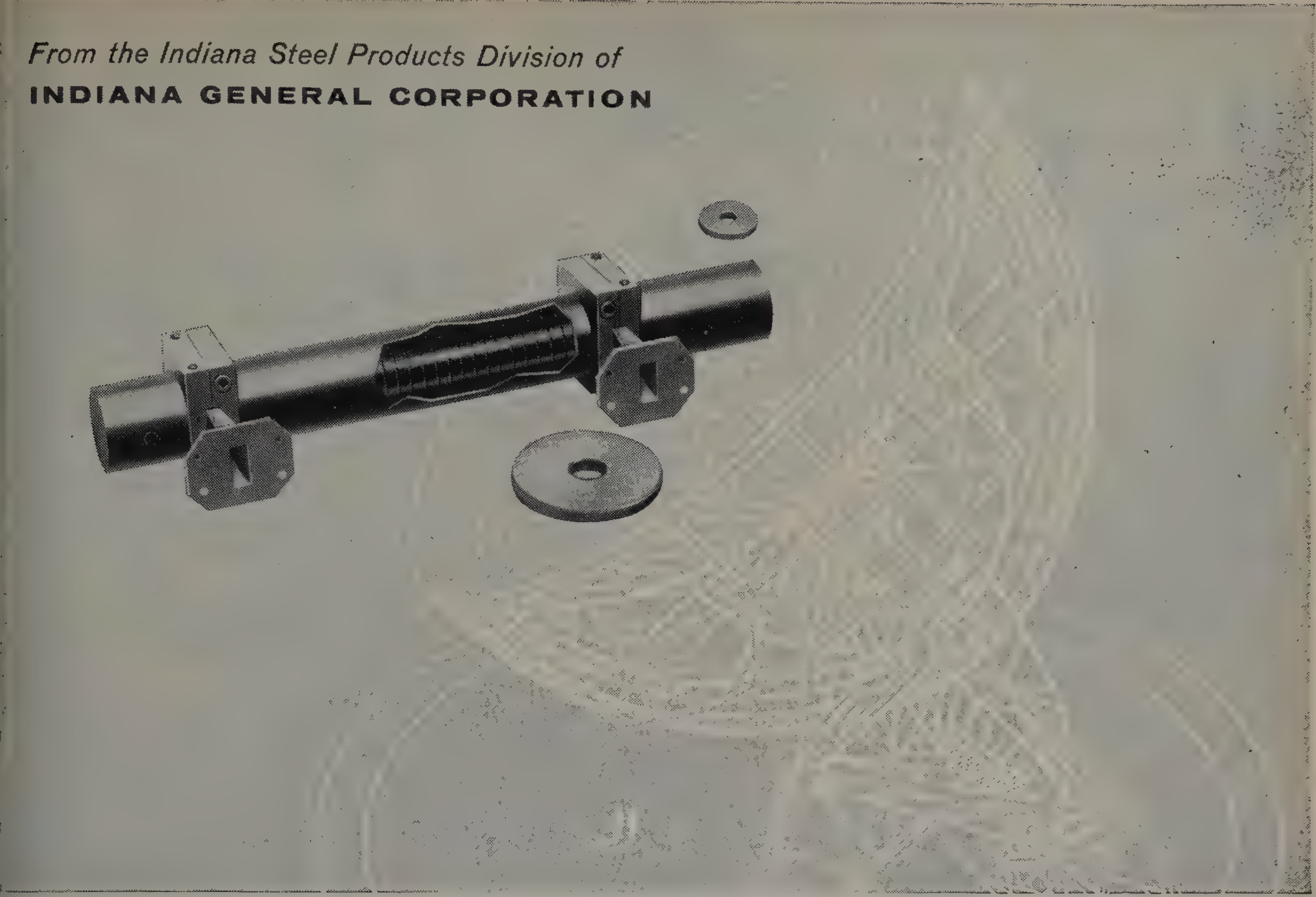

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another ceramic magnet advance for microwave use

Developed by Indiana General's Indiana Steel Products Division, new INDOX VI-A has the highest coercive force of any commercially available magnetic material now in quantity production — plus better resistance to low temperatures, higher residual induction, higher peak energy product.

Indiana General's new INDOX VI-A is a highly oriented barium ferrite material that will effect substantial savings in both material and space in critical equipment such as periodic-focus traveling wave tubes.

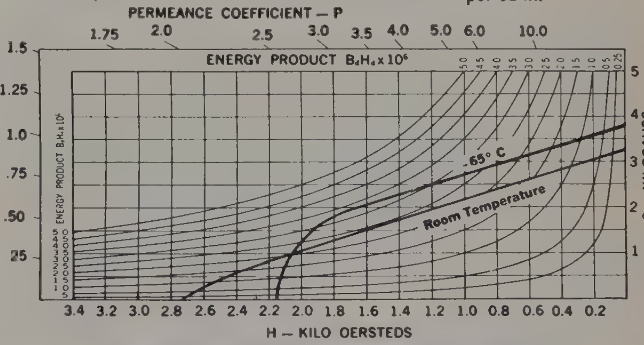
One big advantage is that in many applications INDOX VI-A may be magnetized before assembly. Like INDOX V, INDOX VI-A is best suited for simple shapes: rings, discs, rectangles and squares. Magnet length (pressing direction) is limited to one inch or less; longer units can be built up from separate magnets.

Indiana design engineers worked closely with leading microwave manufacturers in the development of INDOX VI-A. The same characteristics that make this material outstanding for microwave application will open the door to other new applications and improve existing products.

New INDOX VI-A is another in a series of Indiana General's notable achievements in ceramic magnet design. For full details on this or other magnetic materials, write us or check your Indiana sales engineer.

	Room Temperature 20° C	-65° C
Residual Induction (B_r) gauss	3300	3830
Coercive Force (H_c) oersteds	2740	2140
Intrinsic Coercive Force (H_{ci}) oersteds	3000	2300
Peak Energy Product ($B_d H_d$) max.	2.55×10^6	3.4×10^6

Reversible Permeability	1.06
Reversible Temperature Coefficient (magnetic)	−.19% ° C
Magnetizing Field for Saturation, oersteds	10,000
Chemical Composition	$BaFe_{12}O_{19}$
Specific Gravity	4.5 or .162 lb per cu in.



Typical Characteristics and Demagnetization Curve for INDOX VI-A

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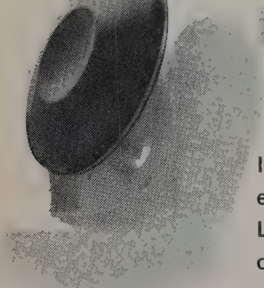

In the field of microwave engineering, Wheeler Laboratories on Long Island occupies a unique position as an industrial laboratory devoted exclusively to consulting and development.

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

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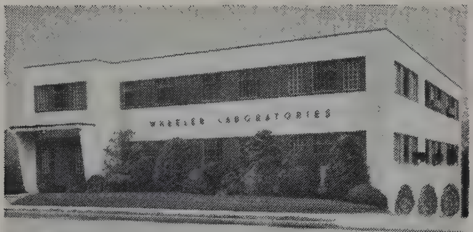

Antenna
Laboratory and
Test Range
Smithtown,
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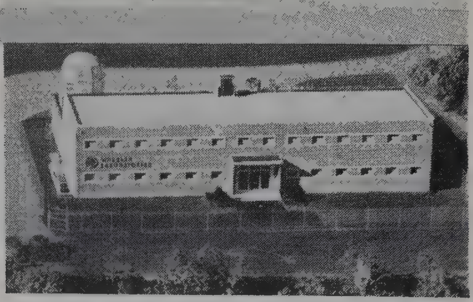

WL HAROLD A. WHEELER
and Engineering Staff

APPLIED MICROWAVE

(*Continued from page 60*)

judge whether or not the company should undertake t produce a given product.

On this last point, Applied Microwave has established rule that it will not enter into a product area that doe not meet at least one of the following conditions: a) A improvement of considerable means upon the performanc of already commercially available equipment; b) an improvement in cost (without diminishing the quality o their product); c) entrance into a field where competition is negligible — in either numbers of companies o quality of products; or d) development of products n currently commercially available.

The principals behind this carefully-developed plan ar young and energetic.

Mr. Burr, at 31, has exceptional ability and depth o background. He has been active in the field of microwave electronics since 1950 when he co-founded Frequenc Standards, Inc., in Asbury Park, N.J., where he served a vice-president and general manager. In 1958, when th company was purchased by National Electric Product Inc., Mr. Burr served as vice-president in charge of marketing. He resigned in the summer of 1960 to form Applied Microwave with J. Gordon Neuberth as his ke associate and vice-president.

Mr. Neuberth is also young (30). An electrical engineering graduate of Johns Hopkins University, he wa principal engineer at the Bendix Radio Division of th Bendix Corporation, working on antenna and passive microwave components for long-range-search radar, surveillance radar and classified missile programs. As principa engineer he had complete responsibility for the design and development of the antenna and all passive microwave components for the AN/FPS-30 Dew Line Rada Set. He also holds several patents on microwav components.

The Middle Part: Room For Everybody

While the two young executives apparently agree with Bacon, they go him one better in that not only should th "debate or examination be the work of many," but th "many" should be exceptionally qualified. Like most up-to-date companies, Applied Microwave believes that strong and diversified staff is its most important immediate asset. On this score, Mr. Neuberth said that thei company intends to have one graduate engineer for ever six production people. [The management of Applied Microwave recognizes, too, that good employee relation within a small company are extremely important. To thi end, it was part of their original design to create really workable profit-sharing plan. At Applied Microwave, every employee will receive a monthly profit and loss statement. Mr. Burr and Mr. Neuberth believe thi practice will produce incentives that will not only increas company profits, but will assure their customers of increasingly high standards of workmanship.]

Thus, in a relatively short time, Applied Microwave ha recruited a sizeable and well-qualified staff of engineering production and sales talent.

Chief Mechanical Engineer is Vernon R. Goldberg (B.S., ME, University of Maryland), former design and test engineer at the Engineer Research and Developmen

(*Continued on page 64*)

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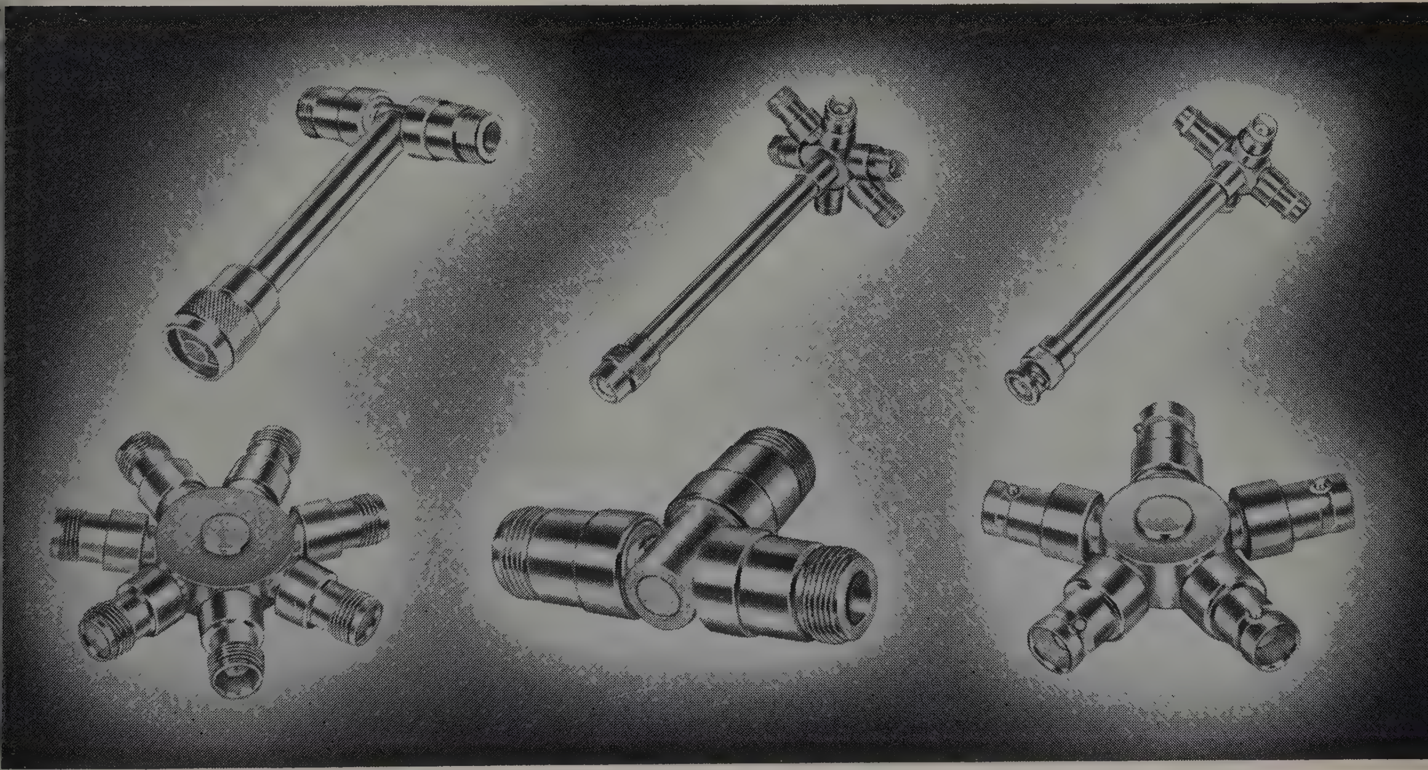

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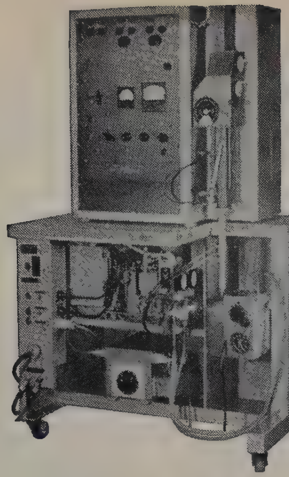

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APPLIED MICROWAVE

(*Continued from page 62*)

Laboratory, Fort Belvoir, Va., and Senior Systems Engineer, Supervisor of Mechanical Design, for the Bendix Corporation's Missile Division at Mishawaka, Ind.

Another valuable addition to Applied Microwave's engineering staff is Glenn Helme (B.S., Physics, Bethany College), who supervised the design and construction of the antenna elements and power dividers network for the SEADAR phased antenna array model and was responsible for all microwave components in the ADVENT Communications Systems. He also has designed three different high-power, coaxial filters for Project Mercury. All this activity was accomplished while he was a member of the Antenna and Microwave Group at Bendix Radio.

Heading Applied Microwave's sales force is a former associate of Mr. Burr, Milton S. Butz, who also was with Frequency Standards in N.J. where he was field Sales Manager. More recently, he was Eastern district manager of the industrial division of the Cubic Corporation of San Diego, Calif. A man of limitless energies, Mr. Butz envisions complete nationwide distribution of Applied Microwave's products in the not too distant future.

Product Line

The product line at Applied Microwave is built around high power passive microwave components and systems. Already it includes a wide variety of devices in the large waveguide sizes (WR 650-WR 2300), and covers the simplest devices, from straight sections and elbows to the more sophisticated items such as slotted lines, directional couplers and hybrids. Applied Microwave feels that the electrical performance of these items is superior to others in the industry and that the mechanical tolerances are tighter.

Also included in the product line are high power filter devices which utilize co-ax or waveguide in construction and can be reflective or absorptive in their rejection characteristics. There is a line of circular waveguide components which includes such tested equipment items as slotted lines and terminations and circularly polarized radiating devices.

Production

As a part of its overall plan, Applied Microwave acquired, in June of this year, a complete and expert machine shop with all its management and production personnel. This company was formerly Service Machine Company of Baltimore. The shop is fully equipped to handle all lathe, milling, grinding and very close tolerance work necessary to produce high quality microwave components. Applied Microwave also enjoys an affiliation with Washington Aluminum Co., of Baltimore, large metal fabricators, which gives them the immediate capability of producing large waveguides and complete antenna systems.

Applied Microwave anticipates increasing its manufacturing facilities this year to triple its productive capacity. This increase will include manufacturing functions and techniques that will keep sub-contracting to a minimum.

Planned is a plating department for copper, nickel, silver, gold and rodium, with sufficient capacity to handle

(*Continued on page 66*)

Discussing a system for space target detection (left to right): Dr. R. W. Bickmore, Technical Assistant to the President; Laboratory managers H. E. Shanks and M. G. Chernin; and M. D. Adcock, Director of the Electromagnetic Systems Division.

A Report from American Systems Incorporated...

Multiple Space-Target Detection

One of the key tasks of modern sensor technology is the determination of the positions and velocities of aerospace vehicles. A particularly important aspect of this problem, now being studied by American Systems Incorporated, is the radar detection of multiple targets. Usually such targets move in relatively small clusters, at high altitude and extremely high velocities. To track the individual objects making up a cluster, new antenna array techniques are under consideration.

This study is being conducted by the Electromagnetic Systems Division, the activities of which encompass research in electromagnetic physics, development of complete sensor systems, and design of special microwave components. Among the scientists and engineers contributing to this work are Dr. R. W. Bickmore and H. E. Shanks, inventors of Time Domain Radiation, and M. G. Chernin, microwave specialist. With active contracts in a number of important areas, the Division is contributing both to basic research, and to the creation of special microwave systems.

The Division's programs include Time Domain and Doppler approaches to measurement of the radiation patterns of large antenna systems, investigation of signal interference problems in areas of high density radio and radar installations, and the development of passive reflectors providing coded target returns.

Front line technical efforts are also under way in six other Divisions of the Company.

INFORMATION SCIENCES

Mathematical and statistical research; computer programming, and advanced programming systems; computation services; digital system studies; logical design; advanced systems analysis.

DATA PROCESSING

Data processing subsystems research and development; logic of command and control complexes; optical recognition systems.

RESEARCH LABORATORIES

Solid state physics and systems; magnetic thin-film research and subsystems; advanced components for information processing.

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Research and development in analytical instruments; detection and monitoring of toxic high-energy missile fuel vapors; gas leak and water vapor detection; on-stream and process control instrumentation.

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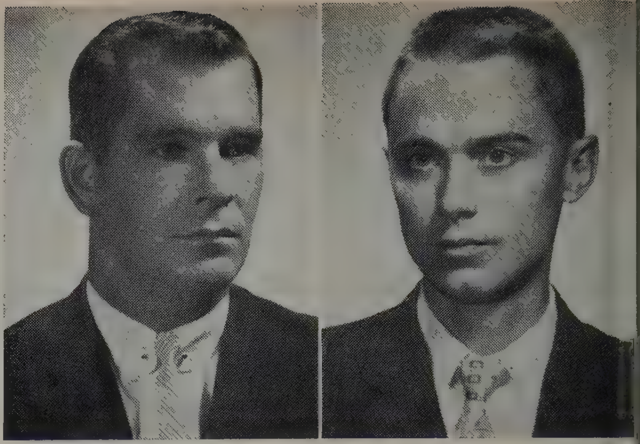

J. Kelsey Burr III (left), Applied Microwave president an J. Gordon Neuberth (right), vice president and chief enginee

APPLIED MICROWAVE

(*Continued from page 64*)

complete microwave component lines for the next three t four years. The type of plating necessary in the micrc wave field requires a high chemical bond to accuracie which in some cases will be .00005. Comprehensive meta joining techniques and equipment are of major importanc in the manufacture of microwave components. Applie Microwave's capabilities now include torch brazing, ove brazing and heliarc welding, with plans underway to in clude dip brazing. The capacity to work extensively i magnesium metal joining is also to be included.

Its affiliate company, Washington Aluminum, is cu rently completing an investigation of a precision castin department, which would give Applied Microwave th capacity to handle all phases of microwave componen manufacture.

The addition to Applied Microwave's present structur will include a temperature and humidity controlled tes area and several reserved areas for manufacturing proce ses requiring highly stable temperature and humidity co ditions.

Test

Applied Microwave's planning paid off again in i selection of a site for their facility. The topography ideal for their fully equipped antenna test range. Wi additions and refinements already underway, the compa will have one 500 ft. range, one 700 ft. range, one 200 ft. range, one 90 ft. variable range and one 180 ft. var able range, with the ability to operate these ranges simu taneously with fully automated equipment.

The Few Again:

Perfection

Perfecting a business is like ship's work — it's neve done. There's always some little thing . . . always a ne product . . . always the change in personnel . . . alway the change in market. The perfection then is a matter degree. And in this sense, only time will tell whether not Applied Microwave's well-laid plans will pay off in high degree of perfection. One thing is certain though its management has followed sound advice in the areas preparation and debate . . . and if they pursue the perfe tion with the same intensity and thoroughness with whic they have started, Applied Microwave Electronics shoul one day be a household word in the industry.

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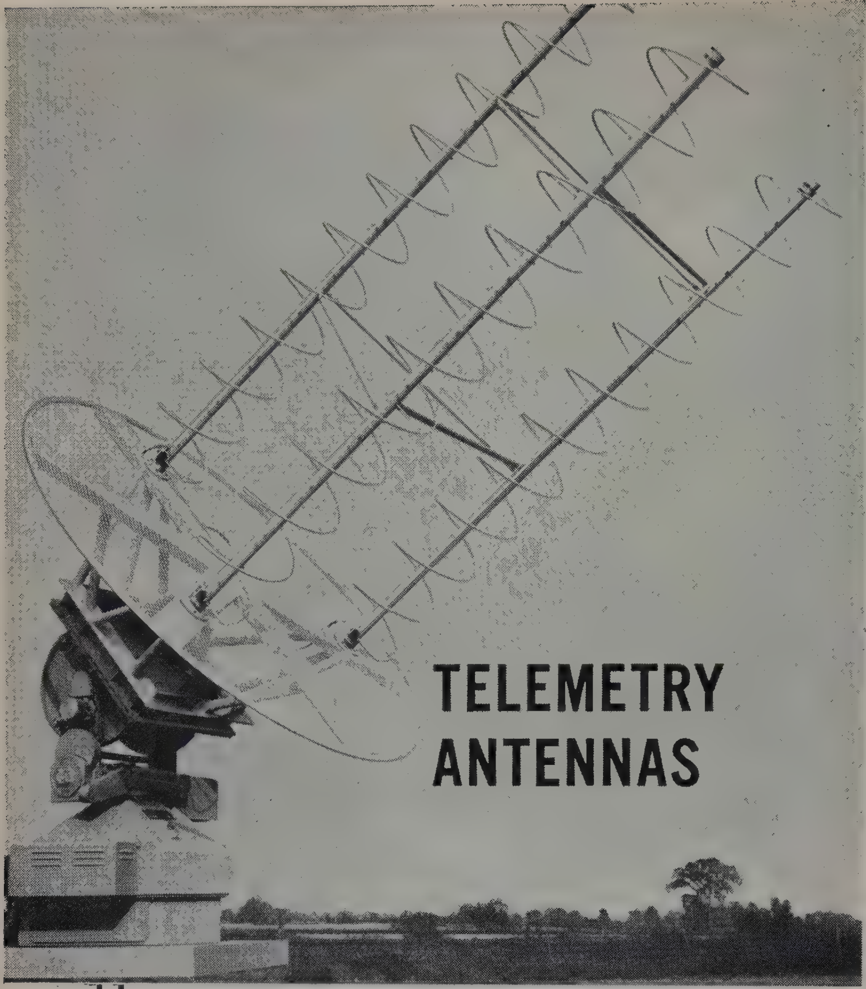

Helical antennas featuring circular polarization for telemetry and ground-based data acquisition, in single or multiple arrays built and tuned for all commonly employed frequency bands. Wide choice of mounts including manual, motor-driven, or automatic tracking. Antennas available for required gains up to 14 db as a single array —higher gain in multiple arrays. 50 ohm output impedance. Sealed weatherproof input connector. Extremely rigid construction.

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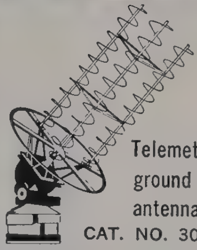
Telemetry and ground base antennas
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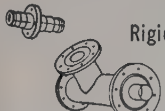
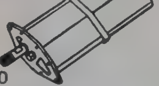
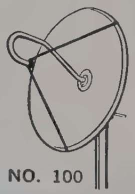
CAT. NO. 500
Large parabolics from 14′ to 32′.







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Industry News

(*Continued from page 57*)

length approximately eight times longer than comparable circuits in conventional klystrons and are capable of producing much higher average powers. Use of the longer circuits, however, will not increase the physical length of the tubes, Sperry said.

—*m w j*—

AFFILIATION OF SANBORN AND HEWLETT-PACKARD COMPLETED

Affiliation of the Sanborn Co., Waltham, Mass., with the Hewlett-Packard Co., Palo Alto, Cal., has become effective.

David Packard, president of Hewlett-Packard Company, and James L. Jenks Jr., Sanborn board chairman, have completed final arrangements in Waltham which make Sanborn a wholly owned subsidiary of Hewlett-Packard.

The business of the Sanborn Co., according to previous announcements by Mr. Packard and Mr. Jenks, will continue as a separate corporation under the Sanborn name. The company will retain its present personnel, management, and policies.

Sanborn, founded in 1917, is a manufacturer of medical diagnostic apparatus including electrocardiographs, multi-channel recording systems for biophysical research and other diagnostic equipment. For the past nine years, the company has also manufactured multi-channel recording systems and various pre-amplifiers for a wide variety of industrial uses.

—*m w j*—

HART JOINS MARK AS MICROWAVE DIVISION MANAGER

Mr. James W. Hart has joined Mark Products, Skokie, Ill., as manager of the Microwave Division, it has been announced. In this capacity he has the responsibility for marketing, engineering and production of UHF grid parabola antennas, solid spun microwave parabolas and government research and development work.

Mr. Hart was formerly with Motorola Inc., Chicago, Ill., as technical program manager in charge of engineering on the AN/MRC-66 VHF Single Sideband program. Before the AN/MRC-66 he headed up development projects on the AN/APS-27 MTI Radar Set, the AN/ALR-3 Receiver, the AN/ALT-2 Transmitter, the AN/ALQ-23 Countermeasures Transmitter, the AN/PRC-21 Communication Pack Set and the AN/ARN-55 I.L.S. System.

Mr. Hart was graduated from Massachusetts Institute of Technology in 1951 and served in the Army as an instructor in Electronic Countermeasures from 1954 to 1956.

—*m w j*—

(*Continued on page 70*)

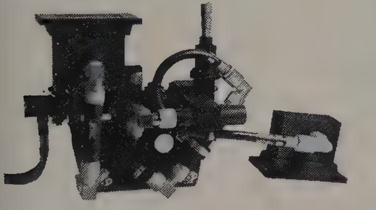
Micromega Turns Your Microwave Problems Into Practical Devices

..And in Production Quantities, Too!

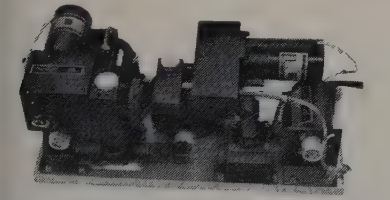
Micromega, rapidly becoming the nation's leading manufacturer of parametric amplifiers, offers the dual advantage of full-scale production experience in microwave devices and sub-systems, plus outstanding capabilities in solving difficult problems. In an age of inflated claims and easy promises, Micromega meets performance specifications with margin to spare. This capability has resulted in notable achievements in parametric amplifiers, frequency (varactor) multipliers, and ferrite devices.

PARAMETRIC AMPLIFIERS

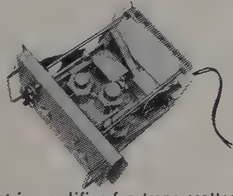
Micromega has produced parametric amplifiers in frequency ranges from UHF to X-Band. Applications include telemetry, tropo-scatter communications systems, and tracking radar. Current quantity production at Micromega includes UHF paramps for tropo-scatter systems and S-Band amplifiers for acquisition radar and missile-tracking systems.



Parametric amplifier in production for airport surveillance radar. Noise figure less than 3db. Band width 10mc at 17db nominal gain. Models tunable over several hundred megacycles or wider bandwidths are available.



Paramp for satellite tracking in the telemetry band 2200-2300mc. Remote-controlled. Tunable over several hundred megacycles. Noise figure 2.0 to 3.0db.

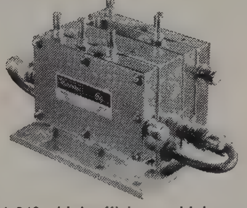


UHF parametric amplifier for tropo-scatter communications. Tunable from 750 to 1000mc. System noise figure 2.5db or less. Bandwidth 10mc at 17db nominal gain. Temperature stabilized. Unattended operation.

FREQUENCY (VARACTOR) MULTIPLIERS

Micromega varactor frequency multipliers utilize lumped constant circuitry in the HF region and strip transmission line techniques in the UHF mircowave region to attain the highest efficiency. Modular construction with 50 ohm interconnections permits combinations of doublers and triplers to be connected for any desired output frequency.

Units may be used separately or with transistor crystal-controlled drivers to form highly stable solid state microwave sources. Applications include telemetry transmitters; frequency synthesizers; and local oscillators for radar communications systems, doppler and MTI systems.



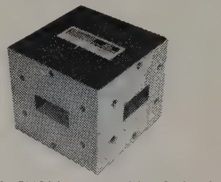
Model FM-6-960, high-efficiency, high-power varactor multiplier is unique in its use of printed strip transmission line resonators at the low frequency of 150mc.

Micromega
FM 3-UHF

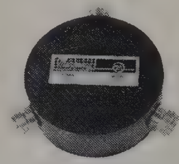
One of four new modular high-power, high-efficiency varactor frequency multipliers. They may be cascaded to provide up to 4 watts output power in the range from 800 to 1250mc when driven from a 10-watt source in HF or VHF region.

FERRITE DEVICES

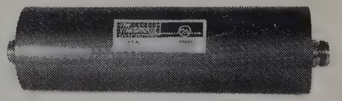
Micromega has produced and delivered in production quantity ferrite components, such as circulators, coaxial isolators, modulators, and variable attenuators — in frequencies from UHF to K_u Band. Circulators have compact configuration, give exceptional performance under rugged, continuous-duty operation.



Typical Model CM210 waveguide T-circulator has frequency range of 6150 to 7550mc; isolation, 20db min.; insertion loss, 0.20db max.



Typical of the line, specifications of Model SL250 coaxial Y-circulator include: frequency range, 3300-3800mc; isolation, 22db min.; insertion loss, 0.30db.



An example of a wide line of coaxial isolators, Model RL-140 is shown here. Specifications: frequency range, 1900-2300mc; isolation, 20db min.; insertion loss, .75db max.; type N connections.

Write for detailed technical data.

Micromega Corporation

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An Affiliate of FXR, Inc.

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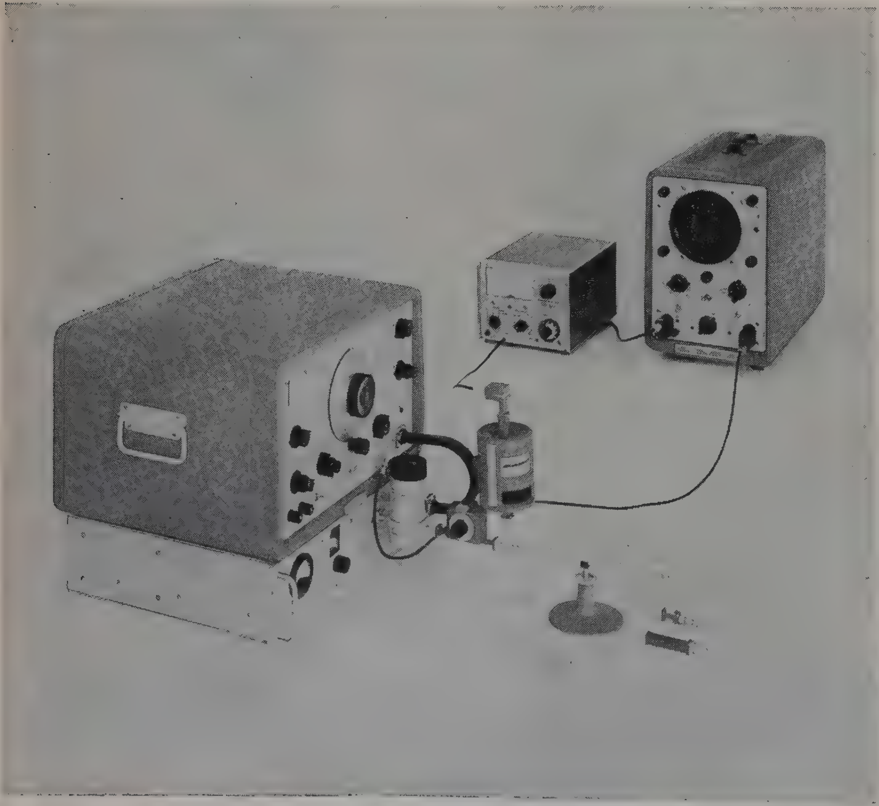
Stewart BWO scores clean sweep

Electronic sweeping as you like it—highly stable and completely dependable—starts with a clean signal from a Stewart backward-wave oscillator. For both laboratory and production use, the electronic sweep oscillators from the leading makers of electronic test instruments use Stewart BWOs almost exclusively. For example, the Hewlett-Packard Model 686C X-band unit, shown below with a frequency doubler in a set-up for sweep frequency testing of waveguide components across the K band, is one of a complete line of 6 H-P sweep oscillators using Stewart BWOs.

Among the reasons that Stewart BWOs make good swept signal sources are their stability, uniformity of power output, and precise repeatability of performance characteristics. Another reason is their reliability: Stewart BWOs are guaranteed for a minimum of 500 hours of operation, and typically last 5000 hours. You are invited to write for data sheets on Stewart BWOs in ranges from 1 through 27 GC.

STEWART
STEWART ENGINEERING COMPANY
Santa Cruz 2, California

Photo courtesy of Hewlett-Packard Company



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Industry News

(*Continued from page 68*)

OBDYKE NAMED CHIEF ENGINEER FOR REMANCO

Appointment of Paul R. Obdyke as chief engineer for Remanco, Inc., Santa Monica, Cal., manufacturer in the field of dynamic radar simulation, has been announced b Ronald Ryall, president.

Mr. Obdyke formerly was associated with International Researc Associates, Los Angeles, Cal., as director of engineering; Telecomputing Corp., North Hollywood, Cal. as senior electronics engineer; Bendix Aviation (Pacific Division), North Hollywood, Cal. as electronics engineer; and Radio Corp. of America, West Los Angeles as senior electronics technician.

— *m w j* —

FINANCIAL NEWS

RAYTHEON REPORTS INCREASE IN SECOND QUARTER EARNINGS

An increase in earnings over the firs quarter of 1961 on virtually the sam sales volume was reported for the second quarter by Raytheon Co., Lexington Mass.

Sales in the second quarter of 196 totaled $142,022,000. Earnings totale $3,389,000 before taxes and $1,644,00 after taxes. Earnings per common shar were 40 cents on 3,888,764 shares no outstanding, after provision for preferre dividends.

This compares with first quarter sale of $138,158,000, and earnings of 3 cents per share on 3,855,045 shares ther outstanding. Total sales in the first si months of 1960 were $277,564,000 wit earnings after taxes and preferred dividend payments of $1.08 per share o 3,723,008 shares outstanding.

— *m w j* —

LORAL REPORTS NEW PROFIT, SALES RECORD FOR FIRST QUARTER

Record high earnings and sales for th first quarter ended June 30, 1961, hav been announced by Loral Electronic Corp., New York, N.Y.

The company reported sales for th three-month period of $9,606,000 a compared with $9,084,000 for the sam period last year. Earnings after taxe were $350,000, equal to 20 cents pe share for the quarter. Previous yea first-quarter earnings were $310,000, c 18 cents per share on a lesser numbe of shares outstanding.

— *m w j* —

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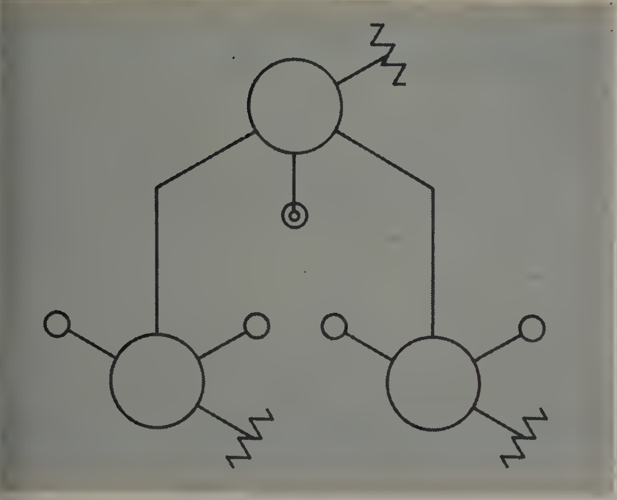
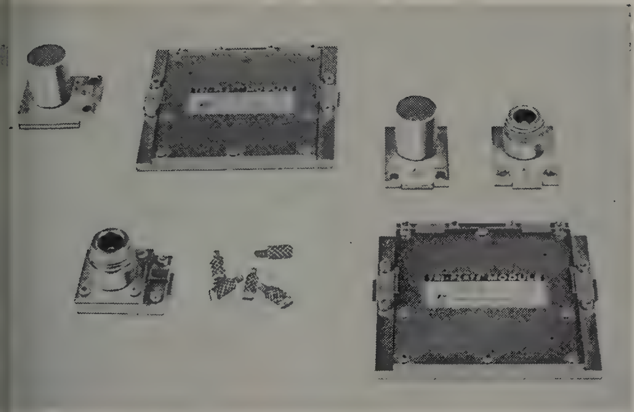
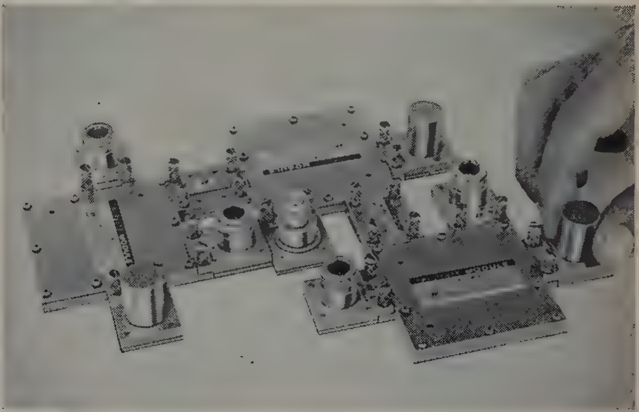
right through production! with Sanders' exclusive strip transmission line techniques and services!



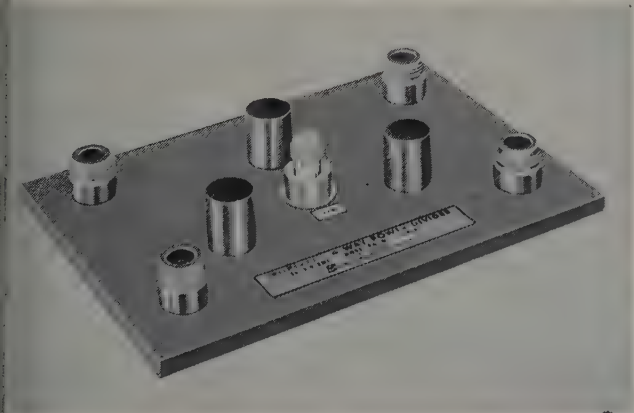
YOUR NEW CIRCUIT IDEAS for microwave applications . . . no matter how new, different or daring . . . can now be breadboarded and tested without costly waste of time, effort and money. All you need is a kit of off-the-shelf . . .



. **BREADBOARDING MODULES!** These exclusive Sanders TRI-PLATE rip transmission line components . . . standard or custom-engineered , include hybrid rings, power dividers, bends, directional couplers, tenuator pads, coax transitions, mounts for transistors, tunnel odes, varactors and switching diodes, etc. . . . all with integral nnectors. You assemble them in minutes with thumbscrews.



WORKING CIRCUIT built with modules ready to test! This subassembly is a balanced, single-end mixer. It could just as well be an oscillator, pulse amplifier, down converter, harmonic generator, parametric amplifier . . . or a radically new microwave development of your own. Performance matches that of conventional plumbing as much as ten times larger and heavier.



RODUCTION PROTOTYPE ready for quantity production! Unitized RI-PLATE "packages" like this 4-way power divider for broad band peration at frequencies up through X band, feature low radiation nd cross talk, precise reproducibility and mil-spec reliability. It eighs 1/10 as much, takes 1/10 the space of waveguide and at ss cost.

QUANTITY PRODUCTION of customized TRI-PLATE "packages", employs automated photo-etching techniques. It reduces costs far below those of coaxial and waveguide units. Sanders' complete TRI-PLATE service . . . modules, engineering, production . . . is always on call. Write for your complete TRI-PLATE Data File with specifications and prices today to: Microwave Products Dept., Sanders Associates, Inc., Nashua, New Hampshire.

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FREQUENCY RANGE — KMC	A-band 26.5–40	V-band 50–75	E-band 60–90	F-band 90–140	TYPICAL PERFORMANCE FOR A, V and E BANDS	REMARKS
Isolator	A110	V110	E110	F110	VSWR 1.25 — Loss .7db — Isolation 17db min., 25 db at center	Bandwidth: 6% A-band, 3% V and E-band. Low power Faraday rotation type isolator
Precision Attenuator	A510	V510	E510	F510	0 — 50db — Insertion loss 1db (not included in calibration) — Error .1db or 2% of reading, whichever is greater.	
Uncalibrated Attenuator	A520	V520	E520	F520	VSWR 1.2 — Attenuation .2db to 25db	Resistance card inserted in waveguide
Phase Shifter	A525	V525	E525	F525	VSWR 1.15 max. — Loss 0.9db — Phase Shift 0–180° min.	Uncalibrated phase shifter. Operates over full waveguide band
Frequency Meter		V550	E550	F550	.2% Accuracy	Covers full waveguide band
Directional Coupler (10, 20db)	A560	V560	E560	F560	VSWR 1.15 — Directivity 20db — 10% Band	
Tunable Detector Mount	A570	V570	E570	F570	Tunes over waveguide band	Micrometer driven short circuit-IN53 crystal or cartridge bolometer
E/H Tuner	A620	V620	E620	F620	Tunes over waveguide band	Micrometer driven non-contacting short circuits
Harmonic Mixer	A730	V730	E730	F730	Built to customer requirements. Can be supplied for 1st to 6th harmonic mixing	Mixer diode built directly into junction of crossed waveguides. Microdot I.F. connector supplied

TRG INC., ANTENNA & MICROWAVE DEPT., 9 UNION SQUARE, SOMERVILLE, MASS. PHONE: MOnument 6-8680

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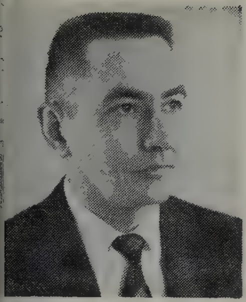
CONTRIBUTORS IN THIS ISSUE



WALTER BEUST received his BEE degree from Rensselaer Polytechnic Institute in 1952 and a MS degree in electrical engineering at Northeastern University in 1961.

In 1952 he joined the Raytheon Company and was engaged in the design of microwave components for missile and radar systems. He left Raytheon in 1954 for a two-year military tour of duty as an ordnance engineer at Aberdeen Proving Grounds in the Army's Scientific and Professional Personnel Program.

After military duty, Mr. Beust returned to Raytheon's Missile and Space Division, Microwave Branch, where he was employed in the development of ferrite devices for the Hawk and Sparrow systems. In 1958 he became section head of the Ferrite Group. In 1960 he was assigned as branch manager of the Microwave Devices Branch and is now engaged in the design and application of microwave devices to Missile and Space programs.

HARVEL N. DAWIRS was born July 10, 1920 in Colorado. He received a BS in electrical engineering in May 1942, and a MSc in mathematics in December 1952.

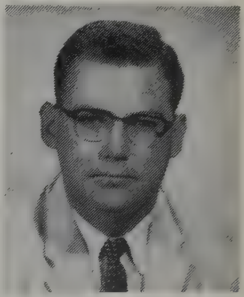
From 1942 to 1947 he was employed in various electrical engineering departments of Westinghouse Electric Corp., and in 1947 and 1948 he worked as a senior engineer in the Pilotless Aircraft Section of the Curtiss Wright Corp.'s Columbus plant. In 1948 he joined the Antenna Laboratory of Ohio State University where he is now an associate supervisor.

Mr. Dawirs is a member of Sigma Xi, Eta Kappa Nu, Pi Mu Epsilon, the United States Naval Institute and is a senior member of the IRE.

HERMAN J. FEIST was born on March 21, 1936 at Carson, North Dakota. He attended Gonzaga University from 1953 to 1955 and received a BS degree in electrical engineering at Seattle University in 1959. He is now working for a MS degree at Seattle University.

In 1955 he joined Boeing Company as an electronics assembler. He became an electronics technician in 1956 and an engineering aide in 1957. Upon obtaining a BS degree in 1959 he became an engineer. He is presently responsible for the calibration equipment and procedures required for the Bomarc B Beacon Test Equipment.

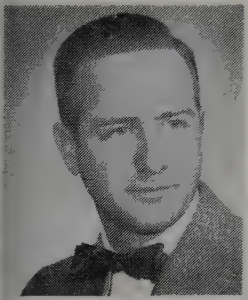
Mr. Feist is a member of the IRE.



WILLARD L. FORD was born on July 17, 1931 in Hartford, Conn. He received a Bachelors degree in electrical engineering from Rensselaer Polytechnic Institute in 1953 and a MS degree in electrical engineering from Northeastern University in 1954.

Since 1953 he has been with the Missile and Space Division of Raytheon Company, Bedford, Mass., where he is a design branch manager in the Radar Systems Department. He has been engaged in the development of CW Radar systems for ground and airborne applications.

Mr. Ford is a member of Sigma Xi, Tau Beta Pi and Eta Kappa Nu.



CLARENCE W. JONES was born in Canton, Maine in 1918. He received a BS degree in electrical engineering from the University of Maine in 1942 and a MS degree in electrical engineering from Washington University in 1952. From 1942 until 1946 he was a staff member at the MIT Radiation Laboratory, transferring for a short period to the MIT Servomechanism Laboratory, and from 1946 to 1952 he was employed by the Emerson Electric Mfg. Company, St. Louis. In 1952, he joined the staff of Lincoln Laboratory and presently is group leader of the Microwave Components Group.

AHARON A. KSIENSKI received the MS and PhD degrees in electrical engineering from the University of Southern California in 1952 and 1958, respectively.

From 1948 to 1951 he was in charge of an Aircraft Electrical School in the Israeli Air Force, and from 1951 to 1952 he attended the University of California as a graduate student and part-time member of the teaching staff. From 1953 to 1955 he was with Wiancko Engineering Company, Pasadena, Calif., engaged in the development of instrumentation systems for the measurement of various flight parameters and in the design of electromechanical transducers. He returned to the University of Southern California in 1955 as a lecturer in mathematics and electrical engineering, and continued graduate research in the field of antennas. In 1958 he joined Hughes Aircraft Company, Culver City, Calif. and is presently senior staff engineer in the Antenna Department, Radar and Missile Electronics Laboratory of the Research and Development Division. He is engaged in research in the field of antennas and antenna systems.

Dr. Ksienski is a member of Phi Kappa Phi, Tau Beta Pi, Eta Kappa Nu and Sigma Xi.

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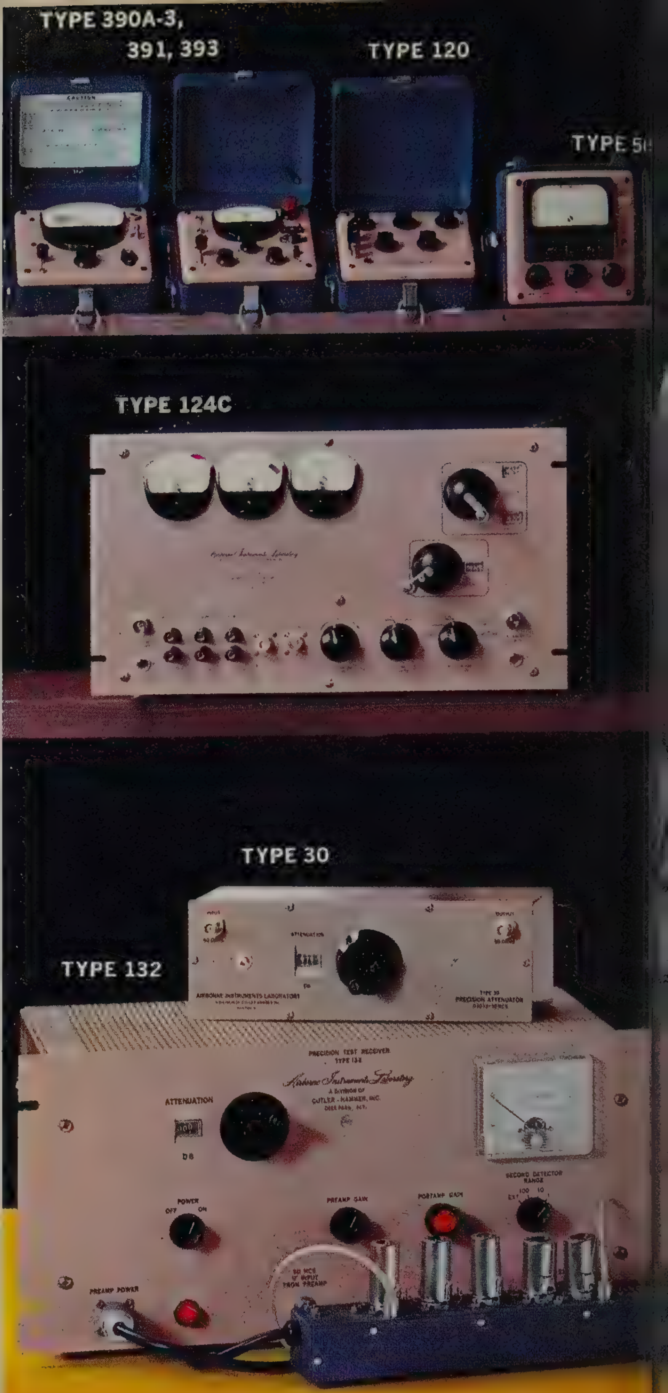

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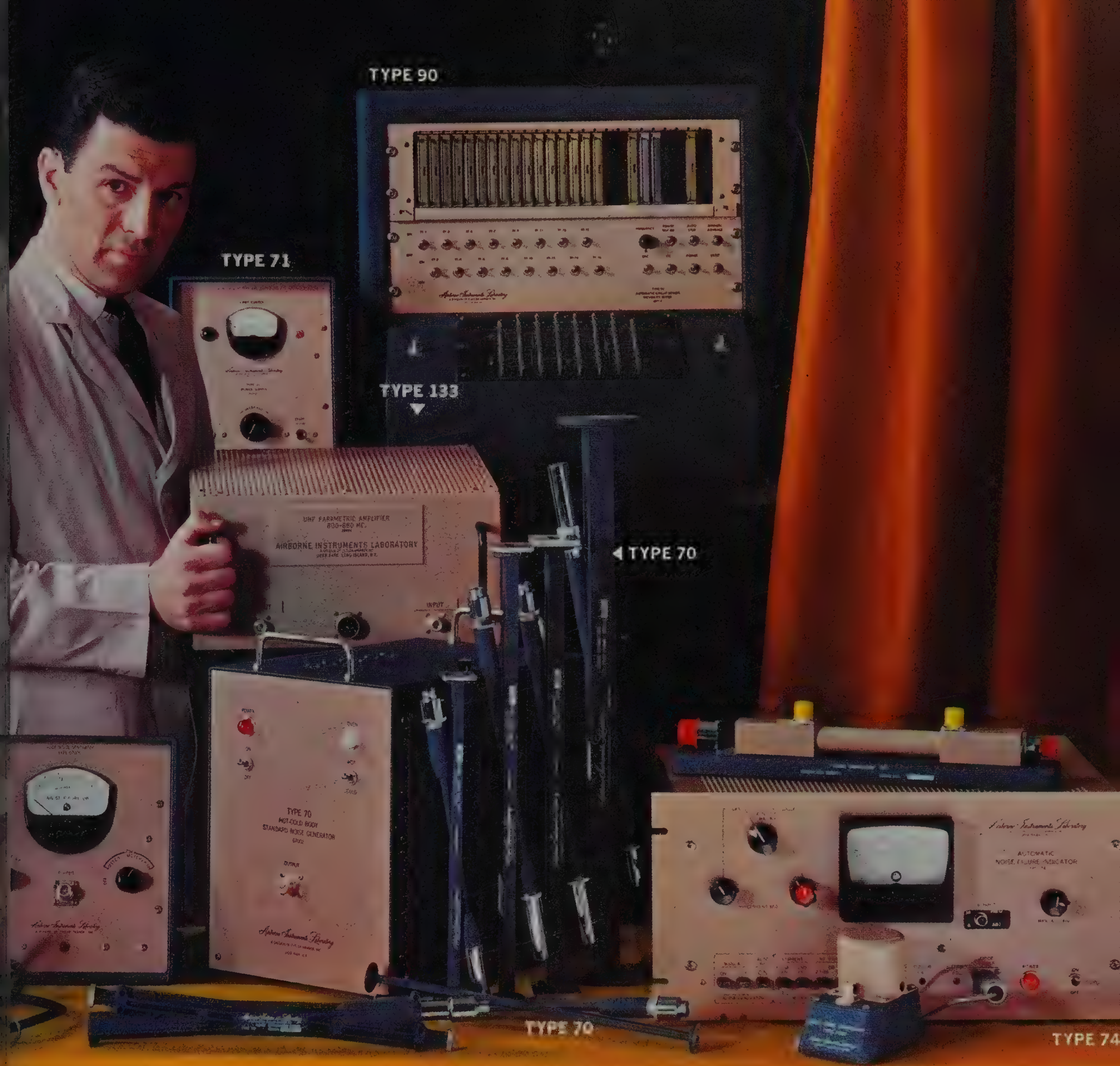
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TYPE 74

ry tool. Calibrate R-F attenuators and uplers. Measure noise figure and selectivity.

EATURES: Incorporates Type 30 attenuator.) and 60 Mc standard frequencies. Noise gure 1.6 db at 30 Mc; 2.4 db at 60 Mc. rices $1,350 and $1,400. Circle publication o. 786.

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EATURES: R-F range 10 Mc to 40 Kmc with ype 70 noise generators. I-F range—30, 60 and 40 to 180 Mc. Noise figure ranges—0 to 25 db, ± 0.5 db; 23 to 36 db, ± 1.0 db. Prices $765 and $830. Circle publication No. 789.

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FIRST OF TWO PARTS

Editor's Note — Some time ago one of the editors pointed out that the antenna field was at a new frontier, where the antenna acted as a signal processing device rather than as a simple transducer. Since that time, appreciable advances have been made: the following paper delineates the various techniques and surveys the state of the art.

Introduction

Modern requirements have greatly increased the deands imposed on the accuracy and versatility of annna systems. These demands are very often highly ecialized, for example, the resolution requirements may of paramount importance while gain may be secondy. This is true in radio astronomy where integration ne may compensate for loss of gain, but resolution essential Satellite tracking, as another example, reires high pointing accuracy for a single target but is ot so stringent regarding resolution which is defined as e ability to distinguish between two targets at a small gular separation. Mapping, on the other hand, does quire high resolution as defined above, since e ability to distinguish two successive points on map is equivalent to the capacity to separate vo closely spaced point targets. The difference etween requirements of gain, pointing accuracy and solution are of little consequence in the case of the onventional antenna such as a lens, a dish or an array. hese antennas are linear two port devices with an output in which gain, resolution and pointing accuracy are gidly correlated by the electromagnetic properties of e structure. Thus, for these devices it is pointless to k whether one characteristic can be optimized at the xpense of the other, for they are all synonymous. Since numerous applications conventional techniques lead prohibitively large and expensive antennas, many tempts have been made to devise techniques that would ot be subject to the rigid constraints of the conventional ntenna.

These efforts resulted in a large group of techniques hich may be termed collectively "signal processing annnas." These techniques which are inherently more exible permit the separation and trading of antenna haracteristics in order to attain the desired objectives ithout running into overwhelming cost, size or tolernce requirements. The signal processing techniques inude multichannel beam forming arrays, switching ntennas, non-linear processing antennas, time modulated ntennas and wide signal band antenna systems. Many f the new schemes exceed the performance of the conentional antenna, but they do so only in regard to a specific characteristic while sacrificing other aspects. This is not a disadvantage, for as mentioned above, the ability to trade characteristics is very desirable and in many cases essential to the accomplishment of particular objectives. It is, however, important to know what characteristics are traded and whether the trade compromises the performance of the system beyond a desired level. A precise evaluation of the system performance is therefore necessary in each particular case.

This paper will describe the most prominent novel schemes, their performance characteristics, areas of tradeoff and reasons behind them. No detailed evaluation of any specific system will be attempted but appropriate guide lines and references will be given to enable the reader to carry out such an evaluation for any system of interest. The first technique to be discussed (Section II) is the Multichannel Array which is really inherent in practically all signal processing antennas. This scheme permits the individual elements of the array to be acted on independently of each other and then to combine them in an arbitrary sequence. This results in a flexible system which can produce simultaneously various outputs and thus provide the versatility and the instantaneous response required by the modern applications such as a "multiple track while scan" radar. Sections III and IV are devoted to techniques which provide the greatest departure from the conventional array and are the most flexible in trading characteristics. These include switching antennas and non-linear antennas. Sections V and VI describe techniques which improve the performance of the antenna by the use of additional parameters. The introduction of new parameters is necessary because of certain radar applications which require both high gain and high resolution and thus do not permit trade offs. One such technique discussed in Section V introduces the time variable as the additional parameter, i.e., the antenna excitation distribution is modulated as a function of time. One of the most important results of this technique is the transfer of tolerance requirement from the mechanical dimension to the time dimension where it is much easier to meet higher tolerances. Another method described in Section VI resorts to the use of frequency bandwidth. The main advantage of the use of the fre-

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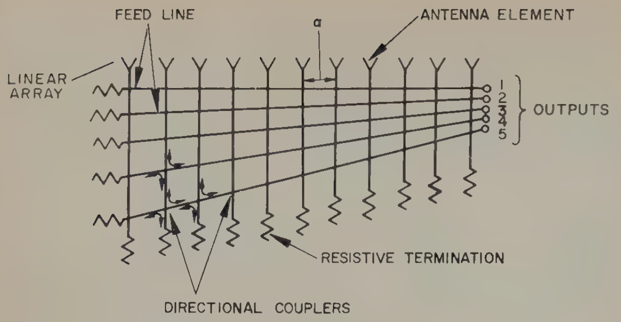


Figure 1 — Stacked beam array.

quency element is that it has a similar effect as that of increasing the antenna dimensions. Wide band width is, of course, being used for other purposes in radar, however, it can be effectively used to both increase directivity and signal-to-noise ratios.

II. Multichannel Arrays

This mode of operation, namely considering each element of the array as an independent antenna and processing its output as a separate signal channel may assume various forms and is in fact a prerequisite for most processing techniques. The signals from the individual elements of the array may be handled in their rf form by an appropriate waveguide network, they may be reduced to an i.f. stage for analog operations, or the signals may be quantized and fed into a digital computer for processing*.

A relatively straightforward application of the multichannel array in its rf form is the formation of stacked beams which permits the simultaneous scanning of a desired angular range. This has been recently implemented by the Maxson Corporation to achieve a large number of simultaneous beams for air traffic control. The scheme[1] uses directional couplers to combine the element outputs in prescribed ways to achieve the multibeam characteristics of the antenna. (See Figure 1)

Each one of the five feed lines produces an independent beam pointing in a different direction. The pointing direction corresponds to the angle for which the contribution of all the antenna elements add in phase. Thus, for example, it is clear that the phase at each element due to the signal from line (2) is progressively delayed as compared to that of line (1). Hence, if line (1) produces a broadside beam, the beam due to line (2) is tilted, or scanned off broadside. The directional coupler beam forming technique preserves the linearity of the antenna and its gain and forms an efficient antenna system.** Having these desirable characteristics of the conventional linear antenna it has likewise most of its shortcomings which result in a rigid tie between aperture size, gain, resolution, element density, sidelobe levels, etc. When on the other hand the individual elements are, for example, cross correlated rather than added, a completely new set of characteristics is obtained as discussed below. The future multichannel array may be envisaged as supplying the inputs to an analog or digital computer which will be capable of combining various groups of elements both linearly and in a variety of non-linear or switching modes to obtain numerous outputs including the conventional pattern. These outputs will result in a joint performance substantially exceeding the characteristics of the conventional antenna. Thus, for example, a high resolution synthetic pattern which might by itself be subject to spurious beam effects can be compared to the ordinary pattern used as a course indicator of target location. Computers may also be used to change the operating mode of an antenna depending on the environmental conditions. For example, an appropriate feedback circuit may change the mode from "non-linear" to "linear" as a function of signal-to-noise ratio since for high signal-to-noise ratio the non-linear mode will provide a higher information rate while at low signal-to-noise ratio the non-linearity may degrade it.[2] Also, appropriate processing may be decided depending on whether a single target or multiple targets are present. Thus the multiport or multichannel array which started as a relatively simple beam forming array will eventually include much more sophisticated operations involving any of the processing techniques discussed below as well as the methods of selecting the processing best fitted for a specified environment.

Many of the above techniques depend on the availability of low noise amplifiers of sufficiently small dimensions that could be used to amplify the signal obtained from the individual element. Fortunately, such amplifiers have been devised and are presently in a development stage.[3,4]

III. Switching Antennas

1. Mills' Cross

The need for extremely large antennas in radio astronomy to obtain very high resolutions prompted the invention of a switching array[5] which attained the desired resolution with a small fraction of the number of elements that would have been required by a conventional array. The technique involves the combination of the outputs of two equal length arrays located at right angles to each other (as a cross) and obtain the equivalent resolution of a two-dimensional planar array of the same overall dimensions. (See Figure 2) The arrays are composed of dipoles spaced λ/2 apart (center to center) and excited to produce broadside directive beams in one plane and omnidirectional or fan beams at right angles to it. The dipoles can, of course, be replaced by any other radiating element as long as all the elements are identical. The processing involves a switching arrangement in which the output of the two arrays are connected alternately in phase and out of phase at a fixed repetition rate, the sum is then fed to a square law detector and the output passed through a filter tuned to the switching frequency. If we denote the output of one array as $F_1(\theta,\phi)$ and the output of the one at right angles as $F_2(\theta,\phi)$ where θ and ϕ are the spherical angular coordinates, the resulting signal will be an alternating signal of amplitude

$$A_m = P_i - P_o \quad (1)$$

where

$$P_i = K(F_1+F_2)^2\,;\quad P_o = K(F_1-F_2)^2 \quad (2)$$

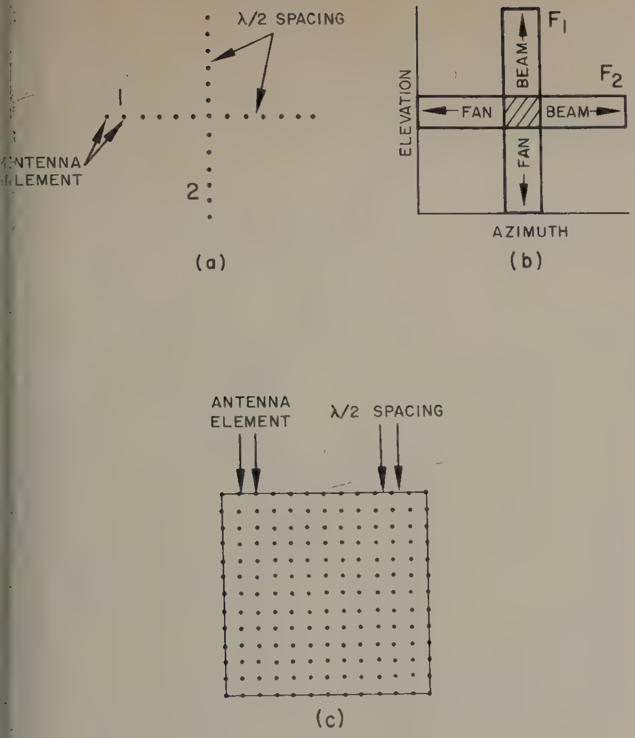
and K represents the gain of the detector. Hence,

$$A_m = 4KF_1F_2 \quad (3)$$

---

* *See for example, V. C. Anderson, "Digital Array Phasing," J. A. S. A., Vol. 32, No. 7, July '60, p. 867.*

** *Certain minor restrictions are imposed on the beam shapes to insure a lossless multibeam formation. See J. L. Allen, "A Theoretical Limitation on the Formation of Lossless Multiple Beams in Linear Arrays," IRE Trans., Vol. AP-9, No. 4, pp. 350-353, July 1960.*



igure 2 — Mills' cross and the equivalent two-dimensional array. a) Mills' cross. b) The patterns produced by a Mills' cross. c) A two-dimensional array with the same directionality as the Mills' cross.

ndicating that the output signal represents the product f the two patterns.

From equation (3) it is clear that unless a target apears in the shaded area of Figure (2b) which is the ntersection of the two patterns F_1 and F_2 it will not be etected. Thus, two antennas each of which has directivity nly in one dimension have combined to produce the irectivity of a two dimensional array (Figure 2c) consisting of N/2 times more elements, where N is the umber of elements in each of the two arrays. The adantages of the system are quite obvious, economy in lements and the required auxiliary equipment, substanal reduction in difficulties of simultaneous adjustment f numerous radiators, the errors produced by mutual oupling and many others. The system, however, has erious shortcomings and its application is limited. The wo most important difficulties are multiple target resoluion and gain. Regarding the first*, from equation (3) is clear that at any time that simultaneous signals are eceived by both antennas the system will interpret it s a signal coming from the main beam. The strength f the recorded return will depend on the relative phase nd amplitude of the two signals. Thus, if targets (soures) are simultaneously present anywhere within the fan eams of the two arrays, these signals will get through. Also, if at the same time that a target is located at the ntersection of the two beams another target is located within one of the two patterns F_1 or F_2 it will distort he signal strength of the center target and may even ompletely mask it depending again on the relative phase nd amplitude of the signals arriving from the two targets. Thus, the system is best suited for single target situations and preferably point targets, since extended targets will produce effects similar to the multiple target situations. The other limitation is gain, or efficiency, depending on the definition one chooses. Since the patterns F_1 and F_2 are each fan beams in one of the planes, the total power received is far larger than the power contained in the intersection beam. Thus the directionality** achieved by the system is obtained by rejecting in the processing stage the majority of the power received by the antenna rather than by concentrating the reception on the desired angular region as in the usual two-dimensional array. The reduction in gain or efficiency may be represented by the ratio of the total energy received to the energy contained in the intersection beam. This leads to the conclusion that the system is limited mostly to applications where the signal to noise ratio is large, such that the loss in gain is well worth the saving achieved in the number of elements, the equipment cost and complexity involved in a complete two-dimensional array. Mills' original idea of introducing a switch between two antennas was extended in two different directions and led on one hand to the idea of switching a whole complex of antennas to obtain various effects from sidelobe reduction to the synthesis of arbitrary patterns, and on the other hand to the group of non-linear processing antennas producing very high directionality by means of very few elements. Most of these processing methods are subject in varying degrees to the same limitations as the Mills' cross. They result in some very definite advantages but one has to pay for them in some other way.

2. *"Logical" Switching Antennas*

The underlying principle of this class of processing antennas[6] is the comparison of signals from different antennas to determine whether the signal is to be accepted or rejected. The decision is implemented by appropriate

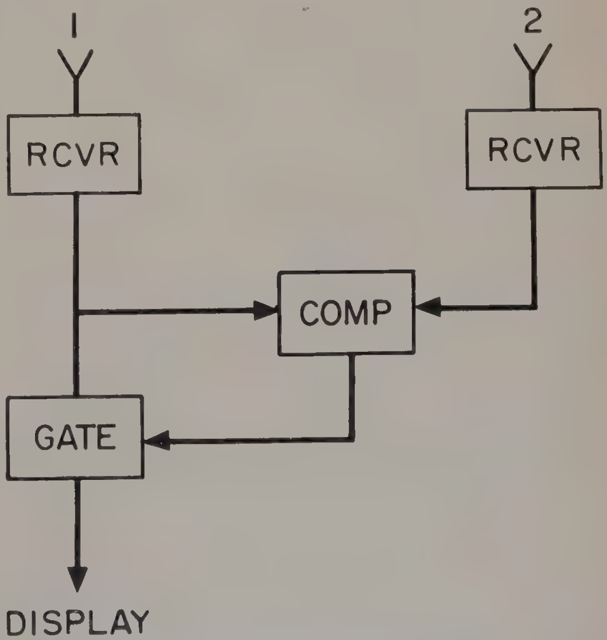


Figure 3 — Logical switching antennas.

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* *We are presently assuming that the target echoes or sources are coherent as in radar. The situation is quite different for incoherent radiation as in radio astronomy — this is discussed later in more detail.*

** *Directionality is defined in this paper as the ability to locate a single point target and is equivalent to directivity only in the sense that it exhibits similar pattern characteristics for a single point target.*

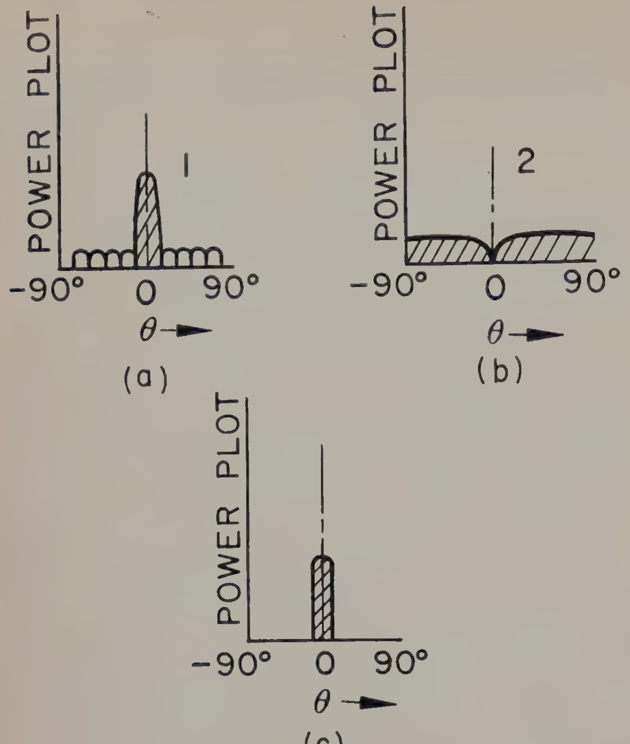

Figure 4 — Sidelobe suppression by logical switching.

gating. The simplest example of such processing is the rejection of the sidelobes of an ordinary directive pattern. Referring to Figures 3 and 4, antenna No. 1 represents the ordinary directive antenna whose pattern is shown in Figure 4a and No. 2 represents an auxiliary antenna which is approximately omnidirectional (Figure 4b). When the signal from No. 1 is larger than that from No. 2, the signal reaches the display; this occurs only if the target is in the main beam. When the target is in the sidelobe range of No. 1, the signal from No. 2 is larger and the gate cuts off the signal. The resultant pattern is shown in Figure (4c). This technique in its most general form employs methods developed in the design of digital computers, namely logical design, to control and program the operations of a whole complex of antennas which may perform various simultaneous operations. Thus, if a set of 2N patterns are available, either from the same antenna by interconnecting the elements in different ways, or from a set of different antennas one can perform various logical operations on the given set. A typical logical equation will take the form:

$$S_d(u) = \sum_{i=1}^{N} S_i \underset{\sim}{[S_{ci} - S_i]} \qquad (4)$$

where $S_d(u)$ is the desired pattern, S_{ci} is the i^{th} control pattern, and S_i is the i^{th} pattern, the symbol (~) stands for digitized, that is, the value in the bracket is converted into two possible states, 1 or 0 depending on whether $S_{ci} > S_i$ or not. The equation prescribes that whenever the control pattern is higher than the detecting pattern *that* portion of the pattern be transmitted to the display. This results in a piecewise approximation of the desired pattern which may be far more accurate than conventional pattern synthesis. One experimental example for the synthesis of a cosecant squared pattern by means of a nine-element array and auxiliary eight-element array is shown in Figure 5. The pattern S_c permits the transmission of signal to the display only for the portion of the pattern S where $S_c > S$, as prescribed by equation (4). The close agreement with the desired pattern and the sharp cut off are highly desirable but unattainable by means of conventional techniques.

The main disadvantages of the switching technique are loss in gain and difficulties in multiple target environments. The reduction in gain is quite clear from the last figure since only a portion of the radiated (or received) energy is utilized. The loss in gain increases as the number of different patterns used to obtain the desired objectives is increased. The loss arises from the fact that the original array (or arrays) has too few elements to produce high directivity or good approximative characteristics. Here the desired objectives are achieved by using all available parameters to obtain close agreement in one portion of the observation range and ignoring the rest, which reduces the gain of the antenna. As to the multiple target environment, the correct operation of the switching system depends on the relative phase, amplitude, range and direction of arrival of the multiple

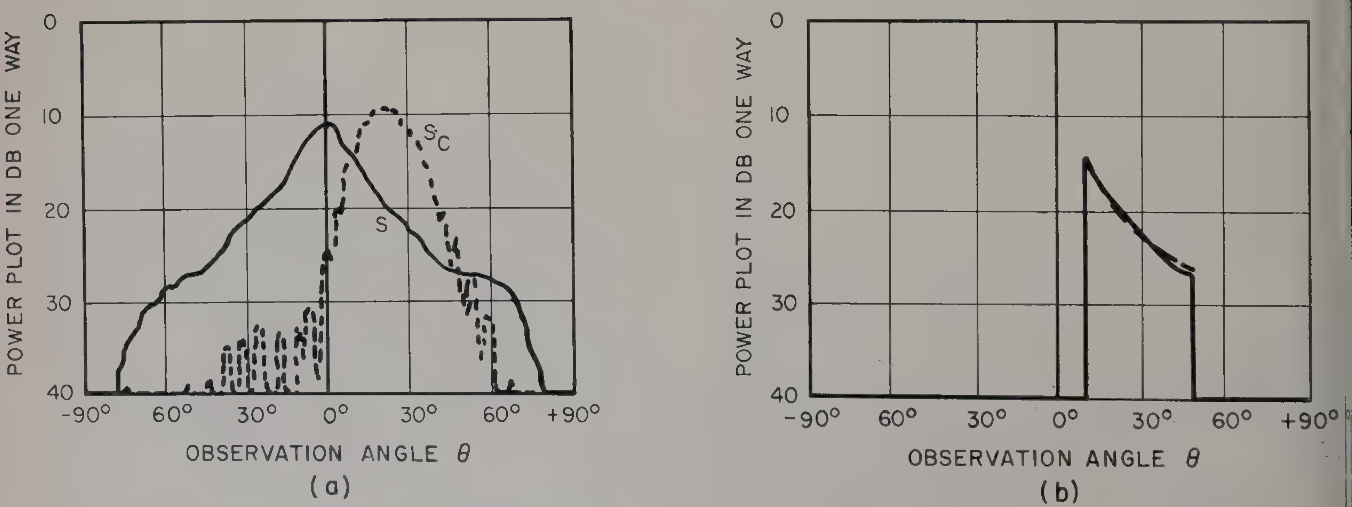

Figure 5 — A cosecant squared beam obtained by logical switching.

a) Superposition of the detecting pattern (solid) and control pattern (dashed).

b) Pattern resulting from logical switching (solid — theoretical, dashed — experimental).

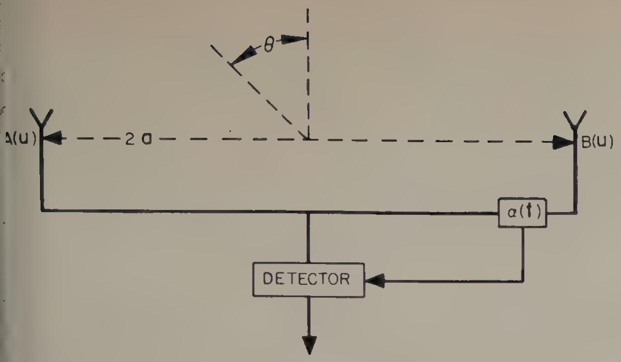

Figure 6 — Covington and Broten interferometer antenna.

gnals. Referring to Figure 5, if in addition to a target ithin the observation angle of interest another target ppears outside it, the signal return from it will be added the first one, which may result in the cut off of both gnals depending on the relative strength of the target hos. Range and velocity gating reduce the chances for ich multiple target interaction; also, scintillation tends decorrelate returns from different targets, but one has be aware of the problem which might be quite serious.

/. Non-Linear Processing

The group of processors falling under this category ave one thing in common: the output is proportional the product, or higher power, of the signals arriving the various antennas. In this sense the Mills' cross may considered as part of this class, however, the objective this group of antennas is to increase the directionality the antenna system within a single dimension rather ian resort to two dimensions. Most of these antenna chniques involve interferometers, and consequently, rry names such as interferometry or interferometer annnas. One of the basic interferometer antennas was esigned by Covington and Broten[7]. This system consts of two antennas whose phase centers are equally splaced from the origin (see Figure 6), A(u) and B(u) ı = sin θ) represent the patterns of the two antennas which are symmetrical in the φ coordinate) and α (t) the time rate of phase introduced by a rotary phase ifter. A passing wave front from a single point source duces voltages in the two antennas given by:

$$\begin{aligned} v_a &= A(u)e^{\,j(\omega t + kau)} \\ v_b &= B(u)e^{\,j(\omega t - kau + \alpha t)} \end{aligned} \qquad (5)$$

here the origin was assumed to be the phase reference, $= \frac{2\pi}{\lambda}$ and ω is the frequency of the incident wave. he power output is given by

$$p = \frac{(v_a + v_b)^2}{2} = \tfrac{1}{2}\left[\frac{A^2(u) + B^2(u)}{2} + A(u)\,B(u)\cos(2\,kau - \alpha t)\right] \qquad (6)$$

From the above equation it is clear that one can pick ff the product term (AB) by means of a phase sensitive etector. Thus, the introduction of the continuous phase ifter results in the multiplication of the two patterns ith an additional factor (cos 2kau) which represents ie phase displacement between antennas A and B. It ight be interesting to compare this result to the direconality of the conventional antenna of same dimensions.

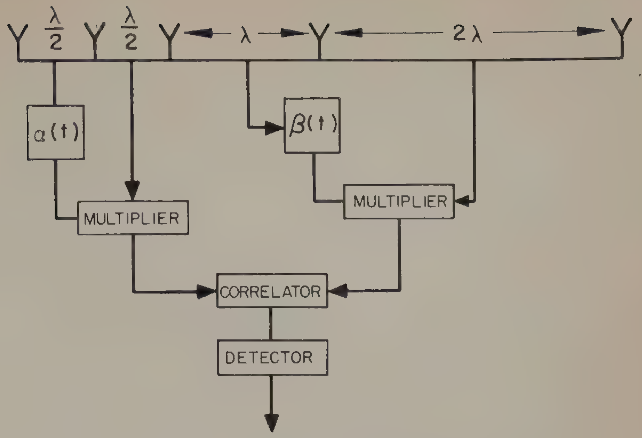

Figure 7 — Drane's correlation array.

Assuming A(u) = B(u), which may be called the element factor, the pattern of the whole array is the product of this element factor and the space factor which in this case is cos (kau). Designating the linear antenna pattern by F_L, we obtain

$$F_L = A(u)\cos kau \qquad (7)$$

while the non-linear antenna (F_{NL}) results in

$$F_{NL} = A^2(u)\cos(2\,kau) \qquad (8)$$

Thus, the directionality is increased first by multiplying (again) by the element factor and then by the equivalent "space factor" which is equal to a linear space factor of twice the physical separation of the two antennas. One may use these additional factors to modify the pattern in various ways, and the question arises as to what is the optimum use of these factors to enhance the performance of the antenna. The pattern $\frac{\sin kau}{kau}$ corresponding to a uniformly illuminated* linear array is desirable for many applications. Accordingly, the attempt was made to produce such a pattern which would correspond, however, to an equivalent aperture larger than the physical size of the actual antenna. This can be achieved if A is chosen to be a uniformly illuminated line source of length 2a and B, an interferometer of element separation 2a. The resulting expression for the product is then given by

$$F(u) = \frac{\sin(kau)}{kau}\cos(kau)\cos(2\,kau) = \frac{\sin 4\,kau}{4\,kau} \qquad (9)$$

The above pattern corresponds to that produced by a line source of overall length 8a, while it was actually produced by an array half as long and resulted in a saving of 3/4 of the elements. (Considering the line source to be replaced by a linear array). The Covington array has been successfully implemented[7,8] and is presently in use in radio astronomy.

The Covington and Broten interferometer may be generalized[9] to include more than one product, as shown in

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* *By "uniformly illuminated" array in the receive case, we mean that the signals obtained from the various elements in the array are weighted equally.*

Figure 7. The scheme results in an apparent uniformly illuminated aperture of twice the overall length of the multiplying array. The main advantage is in the element savings since an array of n elements can produce the effect of a uniformly illuminated $\lambda/2$ spaced array of overall length $\lambda(2^{n-1}-1)$, or the element saving in per cent is given by

$$S=\left(1-\frac{n}{2^{n}-2}\right)\times 100 \qquad (10)$$

which for n equal to 10 is equal approximately to 96 per cent.

The main disadvantage of the scheme is its limitation in a multiple target situation. In the case of simultaneous returns from several targets cross terms will appear which will distort the single target patterns. Thus, the resolving power of the above schemes is not as might be concluded from the single target response and it depends on the relative strength of the targets and their angular separation[10,11]. This applies both to Covington's scheme as well as Drane's arrays, as long as coherent radiation is considered, such as in most radar applications.‡ For incoherent radiation, as in radio astronomy, Covington's apparatus will operate satisfactorily, but Drane's extension may run into varying amounts of trouble as shown below. If we use the image equation (see appendix equation 2A) to represent the output of an antenna and consider the object distribution to consist of two point targets located at u = O and u = a, we obtain,

$$O(u)=\delta(u)+\delta(u-a) \qquad (11)$$

the resulting image is given by

$$I(u')=G(u')+G(u'-a) \qquad (12)$$

For two phase coincident antennas whose gains are given by $G_1(u)$ and $G_2(u)$ the output of the product is given by

$$\begin{aligned}I_1(u')\ I_2(u')&=G_1(u')\ G_2(u')+G_1(u'-a)\ G_2(u'-a)\\&+G_1(u')\ G_2(u'-a)+G_1(u'-a)\ G_2(u') \qquad (13)\end{aligned}$$

If the phase centers of the two antennas are not the same, the cosine of the phase difference has to be included in either $G_1(u)$ or $G_2(u)$. The last two terms of the right hand side of equation (13) consist of cross terms which are undesirable. The equivalent linear array is free of such cross terms which represent the effects of the nonlinear operation. If the two targets are incoherent, the cross terms will vanish when passed through an averaging operation since the output will represent the correlation between two signals which are uncorrelated by definition. Thus, for radio astronomy where the predominant radiation is incoherent, Covington's interferometer will perform as the single target analysis indicates.‡‡ Regarding Drane's extension (Figure 7) involving repeated multiplication and averaging certain of the cross terms may remain. If signals that were correlated already are multiplied, then obviously they are devoid of their original incoherence and represent just products of time averages. However, even if the averaging has not been carried out and four signals are multiplied together and averaged as in the "four-element single correlation inte ferometer" (Figure 7) certain of the cross terms wi appear. This can be seen from the following expression

$$\begin{aligned}F(u)=&[G_1(u)+G_1(u-a)]\ [G_2(u)+G_2(u-a)]\\&[G_3(u)+G_3(u-a)]\ [G_4(u)+G_4(u-a)] \qquad (14\end{aligned}$$

The terms containing an odd number of terms fror the respective sources such as

$$f_1(u)=G_1(u)\ G_2(u)\ G_3(u)\ G_4(u-a) \qquad (15$$

will vanish under averaging, however, those containi an even number of terms such as

$$f_2(u)=G_1(u)\ G_2(u)\ G_3(u-a)\ G_4(u-a) \qquad (16$$

may result in non-vanishing terms since the first tw terms on the right may be correlated and the same true for the last two.‡‡‡ From the above it is clear tha one has to examine in detail the various schemes an determine the true resolution which is directly relate to the types of operations and their sequence, and, c course, the type of sources involved, i.e. coherent, inco herent or partially coherent.

Drane's multiply non-linear scheme has been teste experimentally by Walsh and Band[12] at S-band and b Davenport [13] at X-band. In the first case the final obje tive was to obtain a 1° beam at 40 Mc. Such an antenn would most certainly be excessive in length and equip ment cost if a conventional $\lambda/2$ spaced array were use The results for a single target were fairly good an agreed with theory except for some sidelobe problem The X-band experiment of Davenport was likewise su cessful except for the last multiplication stage where th phase information was lost due to the type of amplifie employed with a consequent reduction of directionali by a factor of two. But, except for this detail the theoret cal prediction was confirmed to within experiment errors.

Another interesting processing approach is that pro posed by Berman and Clay[14]. They suggested sever schemes for obtaining large equivalent arrays by usin various sequences of multiplication and averaging. one scheme (Figure 8) the signal from the first receiv is correlated (multiplied and averaged) with each or of the other three, and then multiplied together. If th distance between the elements is as shown, one obtains

$$\begin{aligned}F(u)&=4\ (\cos\frac{\pi u}{2}\ .\ \cos \pi u\ .\ \cos 4\pi u\\&=\cos\frac{\pi u}{2}+\cos\frac{3\ \pi u}{2}+\cos\frac{5\ \pi u}{2}+\cos\frac{7}{2}\end{aligned}$$

(17

which is the pattern of a uniformly illuminated line array of overall length $7\lambda/2$ while the actual length the array is λ, that is the effective length was multipli by 3.5. Another scheme by Berman and Clay multiplies the outputs together and averages in one operation. On saves on equipment and complexity but the effecti aperture is increased by a smaller factor. The thi scheme uses the outputs of a single pair of elements λ apart to produce a trigonometric polynomial with desir

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‡ *Of course, even in the radar case the radiation is not perfectly coherent due, for example, to scintillation.*

‡‡ *This assumes infinite integration, or averaging, time which for radio astronomy may be fairly well approximation — not so for radar applications.*

‡‡‡ *Even if the targets are not only uncorrelated with each oth but also time incoherent $f_2(u)$ will not vanish if G_1 and have the same phase center and likewise G_3 and G_4.*

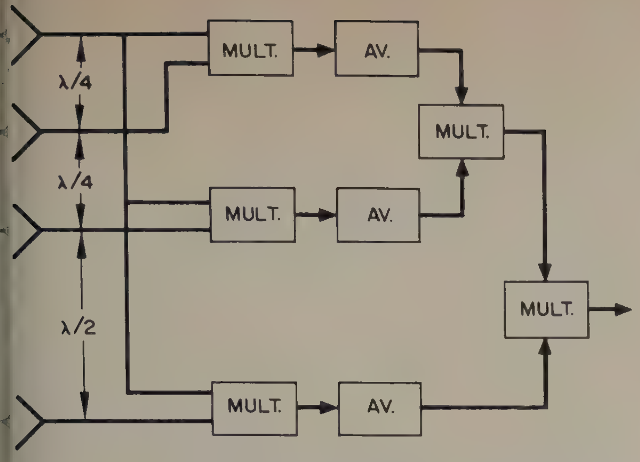

Figure 8 — Berman and Clay multiple correlation array.

oefficients (Figure 9). The output of the averager which is cos $\frac{(\pi u)}{2}$ is raised to various odd powers, modified by ppropriate constants A_n and summed. The output of this computer” is equivalent in directionality to the pattern f a linear array of arbitrary length and excitation distribution, and is given by

$$\sum_{n=1}^{N} A_n \cos^n\left(\frac{\pi u}{2}\right) = \sum_{n=1}^{N} a_n \cos n\pi u \qquad n=1, 3, 5 \ldots N \tag{18}$$

Unlike in the first array which is uniformly illuminated ne can obtain a Tchebyscheff distribution or any other esired illumination by specifying the a_n's which are eadily convertible to the A_n's. As in the previously discussed non-linear processors these results are strictly true nly for single point targets. For multiple targets the esolution properties are severely affected. Since most of Berman and Clay's schemes involve multiple multiplications and correlations the resolution is affected even for ncoherent sources. Again a detailed examination is necessary such as was used for the Covington and Drane arrays to determine to what extent the resolution is affected for each scheme. Such an investigation of several non-linear processing schemes[11] has shown that several schemes do offer substantial advantages even for multiple targets, but on the other hand certain schemes provide completely misleading information in multiple target environment even to the point of completely masking the presence of a target, or on the other hand creating ghost targets. It might be deduced from the above discussion that a non-linear scheme cannot, in principle, have the same imaging properties as a linear array. This, however, is not so, and one example to that effect is shown in Figure 10. If one lets A be a uniformly illuminated line source of length 2a and B a single point with b = 0, it can be shown[11] that the antenna will produce an image of any object (or target) distribution identically equal to that of a uniformly illuminated line source of length 4a. This antenna does not have the same gain or S/N characteristics as the linear array equivalent, but its imaging properties are the same.

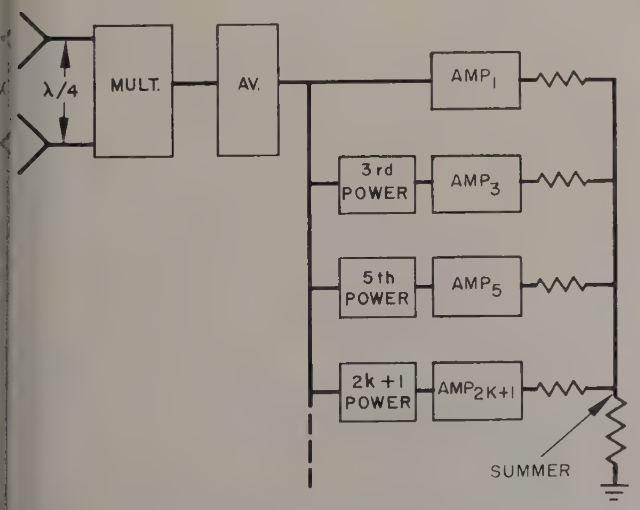

Figure 9 — Berman and Clay polynomial generating array.

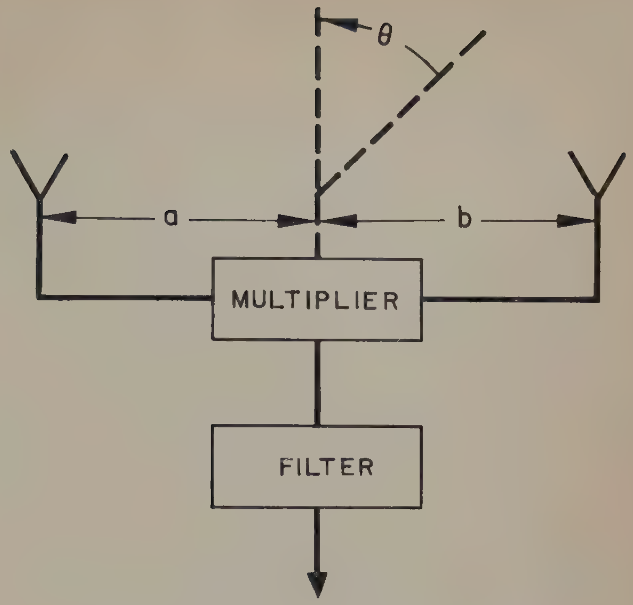

Figure 10 — Non-distorting non-linear array.

One of the principle methods used in processing schemes to improve directionality is the formation of pattern products. This method is very effective, but the nonlinearities introduced to form the products have numerous undesirable side effects such as image distortion or reduction of signal-to-noise ratio. There exists, however, one technique which permits the formation of a pattern product without affecting the linearity of the system. The technique is based on the fact that when one pattern is used to illuminate a target while another to receive the return, the image is that corresponding to that of the product of the patterns. This can be seen from equation 4-A in the appendix where $G_1(u)$ is the transmit pattern while $G_2(u)$ is the receive pattern. This method was utilized by Mattingly[15] to improve the beamwidth and sidelobe structure of an antenna pattern beyond the one obtained by a Tchebyscheff[16] excitation. Assuming that the one way pattern $G_1(u)$ is an nth order Tchebyscheff $T_n(u)$, then the two-way pattern would normally be $[G_1(u)]^2 = T_n^2(u)$. This is a polynomial of order 2n but is not a Tchebyscheff polynomial of order 2n and does not, therefore, yield the minimum sidelobe level for a given beamwidth. One may specify, however, that the product $G_1(u)G_2(u)$ be equal to a Tchebyscheff or order 2n. There are a large number of ways one can form this product but a particularly simple one and most adaptable to implementation is given by,

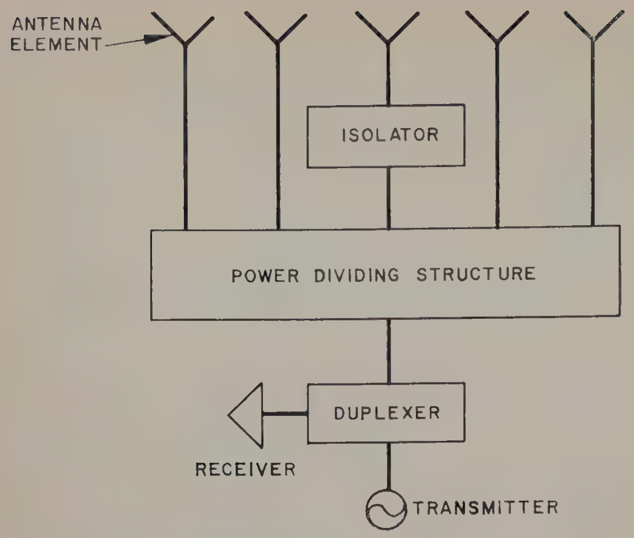

Figure 11 — Mattingly's "non-reciprocal" array.

$$2\,T_n^2 - 1 = T_{2n} \qquad (19)$$

or

$$2\left(T_n - \frac{1}{\sqrt{2}}\right)\left(T_n + \frac{1}{\sqrt{2}}\right) = T_{2n} \qquad (20)$$

Thus, one merely has to change the constant term of the polynomial between transmit and receive and obtain a 10 per cent beamwidth improvement for a given sidelobe level or a 4 to 5 db sidelobe reduction for a given beamwidth. The change of the constant may be obtained by adjusting the excitation of the center element of the array to satisfy equation 20. This was successfully implemented[15] in the manner shown in Figure 11 where the isolator produces the required amount of attenuation in one direction of power flow while leaving it unaltered in the other.

The main limitation of this multiplication technique is that it requires a two-way operation and thus is inapplicable to antenna systems where only the receive mode is available for processing. One may, of course, use the relationships given in equations 19 or 20 for the receive mode by introducing an actual product. That is, a product may be formed between the output of a receiving array representing $(T_n(u) + \frac{1}{\sqrt{2}})$ and the output of the same array after its center element output has been appropriately attenuated.[17] It might even be simpler to carry out directly the operation indicated in equation 19. That is, square the output of the array and subtract from it an appropriate amount of signal derived from the center element of the array. The disadvantage of introducing an actual product is, of course, the non-linearity with its degrading characteristics.

In view of the large number of different nonlinear processing antenna schemes that were devised and their impressive effects on directionality, it is clear that it is a very fertile area of investigation. In fact a relatively modest research effort may lead to a host of new schemes with novel characteristics. The main disadvantage of these techniques is in the difficulty in analyzing them and assessing what was really gained and at what cost. As will be seen (Section VII), the greatest sacrifice is in the signal-to-noise ratio, but this is not always the case and depends to some extent on what the initial signal-to-noise ratio happens to be. However, to assess the complete characteristics of even the simplest kind of nonlinear processing antenna involves laborious computations of a very complex nature. In summary it should be stressed that nonlinear processing is an area where both extensive and intensive research efforts are very desirable.

APPENDIX

Methods for Analyzing Antenna Performance

The output I(u′) of a linear antenna in terms of its far field pattern G(u) and object field strength O(u) is proportional to

$$I(u') = \int_{-1}^{1} G(u-u')\; O(u)\,du \qquad (1\text{-A})$$

where $u = \sin\theta$, and the antenna is pointing in the direction $u' = \theta'$, see Figure 1A. (The integration limits coincide with the ends of the range of visibility of any object.)

In the above equation we have assumed that the antenna is scanned electrically, i.e., by introducing a linear phase variation along the antenna which may be either a continuous aperture or a discrete array. Since the present paper concerns itself with a directive pattern, and those are generally even functions of the argument, equation (1-A) may also be written in a true convolution form

$$I(u') = \int_{-1}^{1} G(u'-u)\; O(u)\,du \qquad (2\text{-A})$$

The above target image relation holds just as well for a two-dimensional antenna where it becomes identical to the optical case of a lens (except for coordinates) from which the notation I and O, image and object respectively have been borrowed.[18]

As the antenna scans the object the output "traces" the image of that object as "seen" by the antenna. In the case that the object is a point target, the image is

$$I(u') = \int G(u'-u)\;\delta(u)\;du = G(u') \qquad (3\text{-A})$$

where $\delta(u)$ is a Dirac delta function representing the point target. The response of the antenna to a point target is thus seen to be equal to the antenna pattern and, in fact, defines the pattern of an antenna the same way as the time impulse defines a linear network.

The above relationships between object and image field strength represent a one-way pattern. For a two-way pattern where the pattern on transmit is given by $G_1(u)$ and the one on receive is given by $G_2(u)$ the output is given by

$$I(u') = \int G_1(u-u')\; G_2(u-u')\; O(u)\,du \qquad (4\text{-A})$$

If the same pattern is used both ways, the output is given by

$$I(u') = \int G^2(u-u')\;du \qquad (5\text{-A})$$

The image equation is a valid representation of the

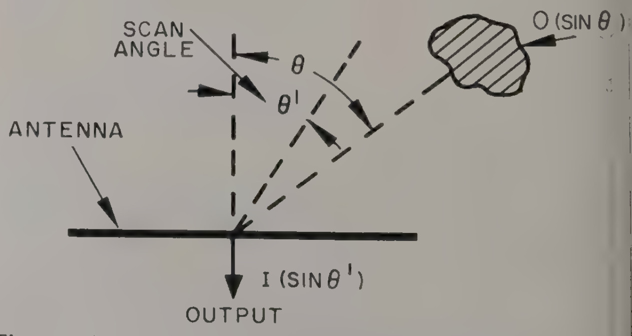

Figure 1-A — Antenna scanning an object to form an "image."

put of a linear antenna for an arbitrary object distribu- and is used in this paper for the analysis of various cessing techniques. This is in contrast to the use of pattern of an antenna as the output which, as was wn, is valid only for a single point target.

n alternative method of analysis is by means of spa- frequency representation. This technique is the di- analog of the frequency plane representation of tem- l signal in ordinary networks, and affords similar ad- ages to those achieved in network theory. This tech- e simplifies certain situations and presents a clearer ure of certain results. It may help both in the analy- nd synthesis of antenna systems.* Taking the Fourier sform of both sides of equation (2-A) we obtain

$$\mathcal{I}(\nu)=\mathcal{G}(\nu)\ \mathcal{O}(\nu) \qquad (6\text{-A})$$

re the script letters represent the transformed func- s and ν is the transform variable. In this representa- it is much easier to assess the effect of the antenna ern. Thus, it is clear, for example, that if the image be as faithful a replica of the object as possible $\mathcal{G}(\nu)$ ld be a constant, and if it extends over the total ctral bandwidth of the object the image will be iden- l to the object. The next natural question is, there- , "how do we obtain such $\mathcal{G}(\nu)$, and what determines properties"? If we remember that the far field pattern iven by[19]

$$G(u)=A\int_{(\text{aperture})} F(x)\ e^{jkxu}\, dx \qquad (7\text{-A})$$

re $k=\frac{2\pi}{\lambda}$, x is the aperture variable and A is con- t independent of x and u, we can see that the aper- distribution F(x) is the same as $\mathcal{G}(\nu)$ (except for nstant) since both are related to the far field pattern a Fourier transform. Thus, the mathematical require- nts imposed on $\mathcal{G}(\nu)$ can be easily translated into the sical requirements imposed on the aperture distribution). The requirement that $\mathcal{G}(\nu)$ be constant means the optimum aperture distribution for fidelity of ob- representation is uniform illumination. On the other d, spectral bandwidth is equivalent to aperture size, , the requirement that $\mathcal{G}(\nu)$ have the same bandwidth he object transform implies an infinitely large aper- . This point, the spectral bandwidth of the signal object is one of the most important differences be- en spatial and temporal signals. The significant part he spectrum of temporal signals is limited to a nar- band. In the spatial domain, however, the small an- r dimension of the object as seen by the antenna, es the significant spectrum of the object to be spread r practically infinite dimensions. In fact, for the most mon object, the point target, the spectrum is constant r $\nu \rightarrow \infty$.

rom the above discussion it is clear that unless we e an infinite aperture the object will be "smoothed" due to the spatial low pass filter characteristics of the enna. Also, objects differing in fine detail requiring their description frequencies which lie outside the band look all alike.[20] In the case of a two-way pat- (equation 5A) the bandwidth is double that of the rture size since the product in the spatial domain gets translated into a convolution in the spatial frequency domain thus, doubling the bandwidth. The disadvantage is that the resulting spectrum is triangular if the aperture illumination is uniform. Thus, additional distortion or smoothing is introduced. A process of restoration, however, suggested by Bracewell and others can construct the image corresponding to a flat spectrum from the image resulting from the triangular one.[20]

The majority of the processing schemes discussed in this paper attempt to extend the spatial bandwidth of the antenna, or its equivalent aperture size, and their performance may be analyzed by examining the spectral characteristics of the resulting images. In the present paper the image equation is used, however, due to the increased interest and application of the spatial frequency approach[11,21] its definition and basic characteristics were presented.

References

1. J. Blass, "Multidirectional Antenna — A New Approach to Stacked Beams," IRE Conv. Rec. 1960, Part I, pp. 48-50.
2. G. O. Young and A. Ksienski, "Signal and Data Processing Antennas," IRE Trans., Vol. MIL-5, No. 2, pp. 91-102, April 1961.
3. A. D. Frost, "Parametric Amplifier Antenna," IRE Proc., Vol. 48, pp. 1163-1164; June 1960.
4. M. E. Pedinoff, "The Negative Conductance Slot Amplifier," Sc. Rp. No. 3, AF19(604)-8386, Hughes Aircraft Co., Culver City, Cal.
5. Mills, B. Y. and Little, A. G., "A High Resolution Aerial System of a New Type," Australian J. Phys., Vol. 6, p. 272, 1953.
6. A. Ksienski, G. G. Comisar and O. R. Price, "Logical Pattern Synthesis," IRE Wescon Conv. Record, Part I, 1959.
7. Covington, A. E. and N. W. Broten, "An Interferometer for Radio Astronomy with a Single-lobed Radiation Pattern," IRE Trans. AP-5, 247 (1957).
8. Covington, A. E. and N. W. Broten, "Compound Interferometers," (author's comment); Proc. IRE, Vol. 46, p. 1951, Dec. 1958.
9. Drane, C. J., Jr., "Phase-modulated Antennas," Air Force Cambridge Research Lab. Tech. Report No. AFCRC-TR-59-138 (AD215374) April 1959.
10. I. W. Linder, "Correlation Processes in Antenna Arrays," Univ. of Calif. Inst. of Eng. Res. Series N 60, Issue No. 301, July, 1960.
11. M. E. Pedinoff and A. Ksienski, "Multiple Target Response of Data Processing Antennas," Scientific Report No. 1, AF19(604)8386, Hughes Aircraft Co., Culver City, Cal., May 1961.
12. Walsh, J. E., and H. E. Band, "Final Report on Interferometer Development," Air Force Contract No. AF19(604)-4535, AFCRC TR-60-120 (Feb. 1960).
13. L. C. Davenport, "Data Processing Antenna with Nonuniformly Spaced Elements," Sixth Nat'l Communication Symposium. Record, pp. 152-160, Oct. 1960.
14. Berman, A., and C. S. Clay, "Theory of Time-Averaged Product Arrays," J. Acoust-Soc. Am. Vol. 29, p. 806; 1957.
15. R. L. Mattingly, "Nonreciprocal Radar Antennas," IRE Proc., Vol. 48, p. 795, April 1960.
16. C. L. Dolph, "A Current Distribution for Broadside Arrays which Optimizes the Relationship between Beamwidth and Sidelobe Level," IRE Proc., Vol. 34, pp. 335-345, June 1946.
17. O. R. Price, " Reduction of Sidelobe Level and Beamwidth of Receiving Antennas," IRE Proc., Vol. 48, p. 1177, June 1960.
18. M. Born and E. Wolf, "Principles of Optics," Pergamon Press, p. 132, 1959.
19. S. Silver, "Microwave Antenna Theory and Design," McGraw-Hill Book Co. Inc., New York, N. Y., p. 174, 1949.
20. R. N. Bracewell and J. A. Roberts, "Aerial Smoothing in Radio Astronomy," Australian J. Physics, Vol. 7, p. 615; 1954.
21. J. B. Smyth, "Space Analysis of Radio Signals," Journal of Research N.B.S., Vol. 650. pp. 293-297, May-June 1961.

Part II of this paper will be concerned with time varying antennas, with wideband signal antenna systems, and with noise considerations. It will appear in the November issue.

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he present discussion excludes supergain arrays whose inclu- on would modify the spatial frequency treatment as well as me of the conclusions of the analysis. Since the practicality of pergain is seriously in doubt, its exclusion does not seriously fect the generality or usefulness of the conclusions.

A Simple Method Of Transforming Impedances Through a Lossless Network

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Introduction

The measurement of impedances is almost always complicated by the fact that the load impedance to be measured is separated from the point at which the measurements are actually made by a network of fittings and adapters which connect the load to the measuring device. For example, the measurement of impedances connected to a slotted line are actually made in the slotted section, removed by a number of half-wavelengths, and various adapters and fittings, from the terminals where the load is connected. Thus the impedance measured is not that of the load at all, but is that impedance transformed through, and distorted by the intervening network.

To accurately determine the load impedance then, the effects of the transition network must be eliminated. This is usually attempted by careful design and construction of the fittings and adapters which connect the load to the slotted line or other measuring device. For example, the development of the transition from the slotted section to the terminals represents a major item in the development of a high quality slotted line. Unfortunately, much of this effort is quite often nullified by the use of adapters required to connect the load to the terminals of the slotted line.

The effects of the fittings separating the load from the slotted section can sometimes be eliminated for accurate impedance measurements, by eliminating the fittings themselves. For example, slotted lines are sometimes constructed to mount directly onto the load to be measured. When one considers the difficulty of making an accurate slotted line it is obvious that this method is usually nc practical.

Probably the best method of eliminating the effects o the transition section is by mathematically transformin the impedance from the point of measurement to the te minals of the load being measured. A number of such im pedance transformations are available for this purpos (see References 1 through 4 of the Bibliography) bu most of these tend to be rather cumbersome due to thei generality, which, in many cases, is not necessary. If th network is lossless, which is true enough for many pract cal purposes, the very simple transformation[5] describe below can be used.

Theory

Consider an arbitrary, but lossless, network mounte on the end of a transmission line as shown in Figure Now choose input terminals to be located at a point in th transmission line at which a null occurs when the outpu terminals are short circuited. It is this choice of inpu terminals that is responsible for the resulting impedanc (or admittance) transformation, for, under these circum stances (1) of the following familiar network equations,

$$V_i = aV_o + bI_o \tag{1}$$

$$I_i = cV_o + dI_o \tag{2}$$

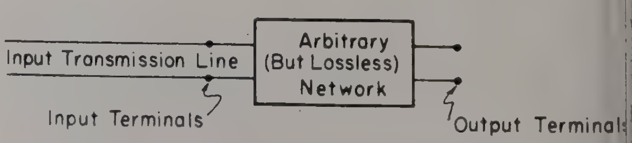

Figure 1 — Typical network configuration.

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* *Sponsored in part by Boeing Aircraft Company, Seattle, Washington.*

comes

3) $$0=a\cdot 0+bI_o$$

hich implies that

4) $$b=0$$

here

V_i is the voltage across the input terminals,
V_o is the voltage across the output terminals,
I_i is the current into the input terminals,
I_o is the current out of the output terminals, and
a, b, c, and d are the "general network parameters" or the "abcd constants" of the network.

With b=0 from (4), Equation (1) becomes

5) $$V_i=aV_o$$

r the defined network.

Dividing (2) by (5) yields

5) $$\frac{I_i}{V_i}=\frac{c}{a}+\frac{d}{a}\frac{I_o}{V_o}$$

7) $$Y_i=K_1+K_oY_o$$

here

$Y_i=\frac{I_i}{V_i}$ is the admittance seen at the input terminals when

$Y_o=\frac{I_o}{V_o}$ is the admittance across the output terminals.

If the output terminals are open circuited, the input ad-ittance, by (7), becomes

3) $$Y_i=jB_{oc}=K_1+K_o\cdot 0$$

here $Y_i=jB_{oc}$ is the "open circuit susceptance" of the etwork which must be purely imaginary due to the loss-ss nature of the network.

Thus it follows that

) $$K_1=jB_{oc}$$

d hence, that

10) $$Y_i=K_oY_o+jB_{oc}$$

here B_{oc} is a real number.

Now if any pure susceptance jB_o, other than an open or short circuit, is connected across the output terminals, e input admittance, according to (10), will be

11) $$Y_i=K_ojB_o+jB_{oc}$$

here Y_i must be purely susceptive since there is no loss the circuit. That is

12) $$Y_i=jB_i$$

here B_i is real, when $Y_o=jB_o$. Equating (11) and (12) elds

13) $$B_i=K_oB_o+B_{oc}$$

hich shows that K_o must be a real number, since B_i, B_o d B_{oc} are all real.

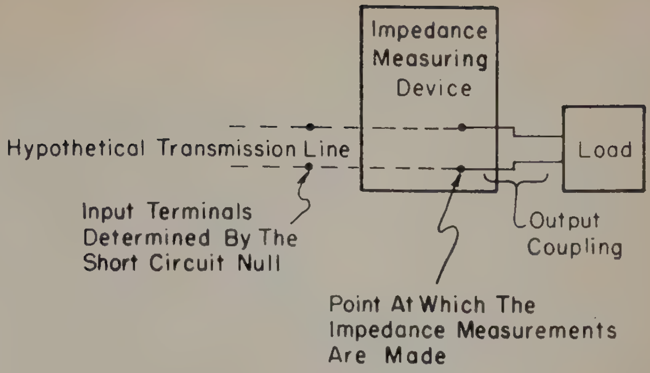
Impedance Measuring Device
Load
Hypothetical Transmission Line
Input Terminals Determined By The Short Circuit Null
Output Coupling
Point At Which The Impedance Measurements Are Made

Figure 2 — Use of hypothetical input transmission line for the location of the input terminals.

Thus, once the input terminals are located and the real constants K_o and B_{oc} have been determined, (10) proves to be a very simple relation between the admittances at the output terminals and the input terminals in the input transmission line.

Calibration

In order to use the admittance transformation described above, it is necessary to locate the input terminals and determine the corresponding values of the constants B_{oc} and K_o.

The location of the input terminals is simply the location of a voltage null in the input transmission line when the output terminals are short circuited. This is particularly easy when the input transmission line is a slotted section. In any case the position of such a null can be easily determined by the use of a Smith Chart or other means when the impedance is known at any point in the input transmission line. Actually the input transmission line does not have to exist physically but can be a hypothetical line assumed to be connected to the network at the point at which the impedance measurements are made as shown in Figure 2. The null position on this hypothetical line can be determined just as if the line really existed, and used as a common reference point for the transformation of admittances from the point of measurement to the output terminals.

Once the input terminals have been located the constants can be determined in a number of ways, the simplest of which consists of connecting any known conductance G_o across the output terminals. Then, by (10), the input admittance will be

(14) $$Y_i=K_oG_o+jB_{oc}.$$

Now the input admittance can be measured to be

(15) $$Y_i=G_i+jB_i$$

in which case the constants are simply

(16) $$K_o=\frac{G_i}{G_o}$$

and

(17) $$B_{oc}=B_i$$

which follow from equating the real and imaginary parts of (14) and (15).

Actually any known real admittance, G_o+jB_o, with a

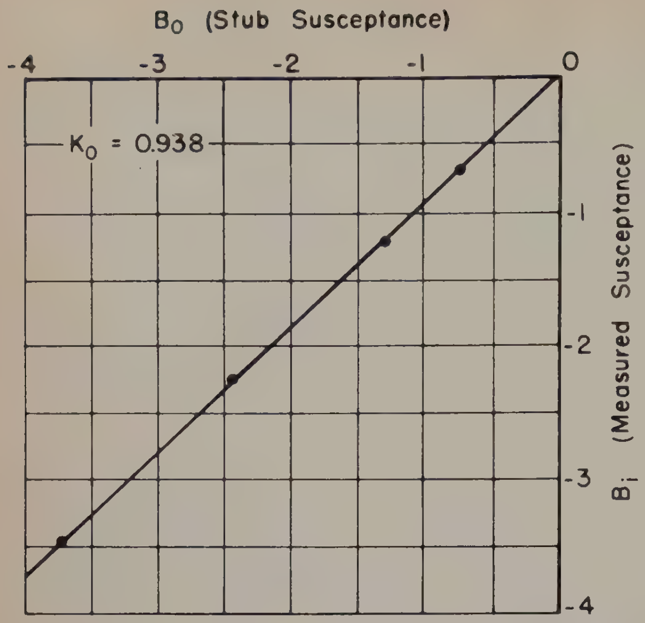

Figure 3 — Determination of the calibration constants of the slotted line adapter shown in Figure 4, at 650 Mc. (All admittances are normalized to 0.02 mhos.)

real part can be used to calibrate the transition network, since the input admittance will, by 10, be

(18) $$Y_i=K_oG_o+jK_oB_o+jB_{oc}.$$

The constants

(19) $$K_o=\frac{G_i}{G_o}$$

and

(20) $$B_{oc}=B_i-K_oB_o$$

will follow by equating the real and imaginary parts of (18) and the measured input admittance of

(15) $$Y_i=G_i+jB_i$$

as before. The value of K_o from (19) can be substituted into (20) to give

(21) $$B_{oc}=B_i-\frac{G_i}{G_o}B_o$$

in terms of known and measured values.

Purely susceptive terminations can also be used to determine the constants B_{oc} and K_o except that two measurements with different terminations, neither of which can be a short circuit, will be required. It has been shown in the theoretical section that B_{oc} is the input susceptance when the output terminals are open circuited. With B_{oc} so determined, one other independent susceptive termination is required to determine the value of K_o by the use of (13). This procedure is not very practical since it is difficult to obtain a true open circuit at the output terminals due to radiation, stray capacitance and various end effects.

However any two independent susceptive terminations can be used to calibrate the transition network. Equation

(13) $$B_i=K_oB_o+B_{oc}$$

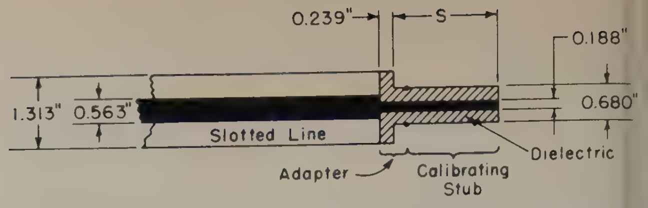

Figure 4 — Longitudinal section of slotted line and adapter with calibrating stub.

is true for any purely susceptive termination $Y_o=jB_o$, and is a real linear equation in B_i and B_o. That is, measured values of input susceptance B_i plotted as a function of the terminating susceptance B_o, will lie in a straight line of slope K_o with a B_i intercept of B_{oc}. Thus, any two independent impedance measurements will establish the straight line and hence, determine the constants K_o and B_{oc}. Any number of measurements may be plotted, however, to provide a statistical average and, hence, increase the accuracy of the calibration.

A very precise calibration can be obtained if the calibrating susceptance at the output terminals is obtained by means of a precise sliding short circuited stub in which the position of the short circuit is determined by means of a micrometer, and the corresponding null positions are also located in a high quality slotted section by means of a micrometer. The nulls themselves will be very sharp and easy to locate since only susceptances are involved. (The no-loss assumption may be checked by the sharpness of the nulls.) Note that no amplitude or VSWR measurements are required, but only micrometer measurements of short circuit and sharp null positions which can be made with great accuracy.

It is also possible to construct fixed, short-circuited, terminating stubs with great accuracy. These can be used as primary reference standards since the susceptance can be calculated from the physical dimensions.

Thus a number of accurate measurements can be made and averaged to obtain a calibration whose precision is limited only by the accuracy of the slotted section used to make the measurements. An example of such a calibration is shown in Figure 3 where the calibration constants are determined for an adapter on the end of a slotted line as shown in Figure 4. In this example four different stub lengths, s, were used to obtain the four calibration points plotted.

It may be observed that, while the value of K_o is easily and accurately determined from the slope of the line through the plotted points, it is not so easy to determine the B_i intercept, which is B_{oc}, with the same degree of accuracy. This could be accomplished by enlarging the graph which is not very practical. A more convenient method is obtained by subtracting the stub admittance B_o, from both sides of (13) to obtain

(22) $$(B_i-B_o)=(K_o-1)\,B_o+B_{oc}.$$

The differences (B_i-B_o) are then plotted as a function of B_o. This allows the ordinate scale (B_i-B_o) to be greatly expanded to obtain B_{oc} with an accuracy comparable to that of the measurements. It will be noted that the slope of the line through the plotted points will now be (K_o-1) so that K_o will be equal to one plus the slope.

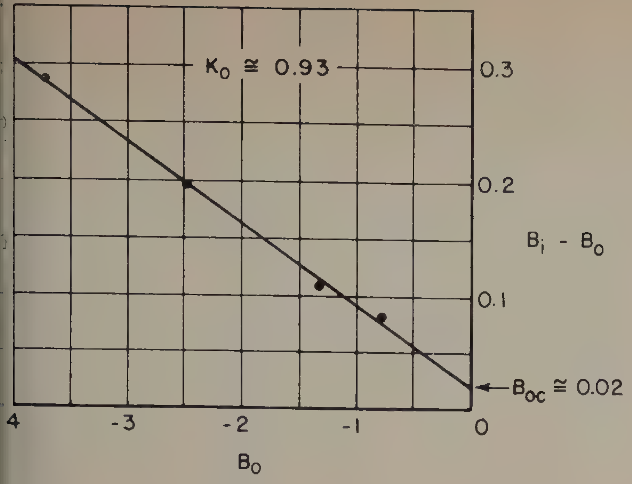

Figure 5 — Determination of the calibration constants of the adapter shown in Figure 4, at 650 Mc by plotting differences. (All admittances are normalized to 0.02 mhos.)

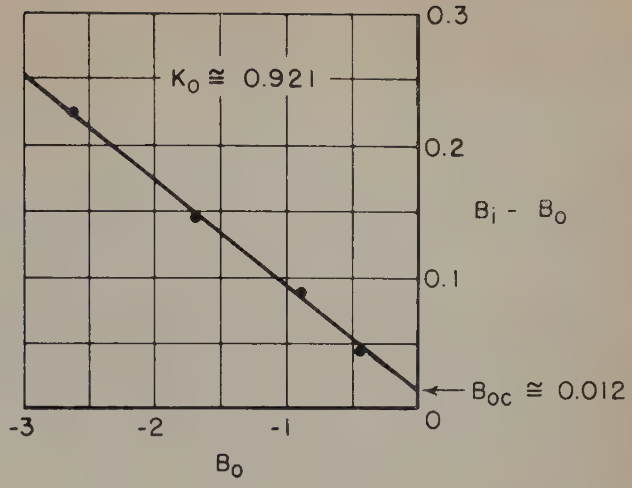

Figure 6 — Determination of the calibration constants of the adapter shown in Figure 4, at 900 Mc by plotting differences. (All admittances are normalized to 0.02 mhos.)

Figures 5 and 6 show examples of this procedure for obtaining the calibration constants of the adapter shown in Figure 4. Figures 3 and 5 may be compared as examples of the two graphical procedures for obtaining the calibration constants at the same frequency.

Application

As implied in the theory and calibration sections, an important application of the admittance transformation procedure is that of making accurate impedance measurements through the inevitable network of fittings and adapters which connect the load to be measured to the measuring device. Once the network has been calibrated, the measurements which have been accurately made with the slotted section or other measuring device, can be simply transformed to the output terminals to determine the admittance there with the same accuracy. Thus the effects of the entire network are eliminated by the calibration and transformation.

In transforming admittances from the input terminals, where the measurements are made, to the output terminals, an expression of the output admittance in terms of the input admittance would be more convenient than (10) in which the input admittance is expressed in terms of the output admittance. Such an equation is easily obtained by solving (10) for Y_o in terms of Y_i to obtain

$$Y_o = \frac{Y_i}{K_o} - j\,\frac{B_{oc}}{K_o} \tag{23}$$

or

$$Y_o = K_i Y_i + jB_{ic} \tag{24}$$

where

$$K_i = \frac{1}{K_o} \tag{25}$$

and

$$B_{ic} = \frac{-B_{oc}}{K_o}\,. \tag{26}$$

In addition to the measurement of impedances (or admittances) the transformation procedure is useful in calibrating networks containing complex transition sections, long runs of transmission line and the like, the effects of which are difficult to calculate. For example, a long and complex run of transmission line, such as is often required to connect equipment to an antenna, may be quickly and easily calibrated by means of a short circuit, a known real load at the antenna terminals and an impedance measuring device at the other end.

The calibration procedure can be used to investigate the effects of the junctions and the transition sections themselves. For example, the effects of a small discontinuity in a transmission line can be measured quite accurately,[6,7] not only to eliminate its effects in the accurate measurements of admittances,[7] but also to learn more about the effects of the discontinuity itself.[6] The input and output transmission lines can be entirely different so that transitions between the two can be investigated by means of the calibration procedure.

The impedance transformation can also be useful in theoretical calculations where a large number of admittances are to be transformed through a complex network. The procedure is always simple with the linear transformation being merely a multiplication by a real number and the addition of an imaginary component, regardless of the complexity of the network. Thus it is only necessary to work through the details of the network in order to determine the input terminals and the calibration constants.

Discussion

The admittance transformation presented provides a simple procedure for transforming admittances and hence impedances, through any four terminal network. The calibration required for this transformation is quite easy to perform and removes the effects of the entire network between the input and output terminals. The simplicity of the procedure is not affected by the complexity of the network, and a little care can yield very accurate results. The only requirement is that the network be lossless, or reasonably so for good approximations.

Equation (10) suggests the equivalent circuit shown in Figure 7. The somewhat simpler equivalent circuit of Figure 8 can be obtained with the additional require-

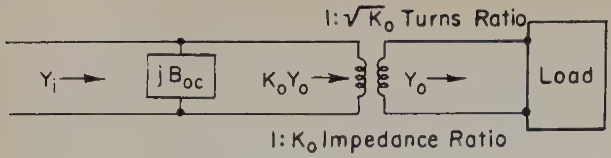

Figure 7 — Equivalent circuit of transformation $Y_i = K_oY_o + jB_{oc}$.

ment that an open circuit at the output terminals appears as an open circuit at the input. This requires the simultaneous selection of both the input and output terminals of the network[8] which is rather involved and is hardly worth the effort when one considers that it only eliminates the additive constant. That is, if an open circuit at the output terminals is transformed into an open circuit at the input terminals, (2) becomes

$$0 = CV_o + d \cdot 0 \tag{27}$$

or

$$C = 0 \tag{28}$$

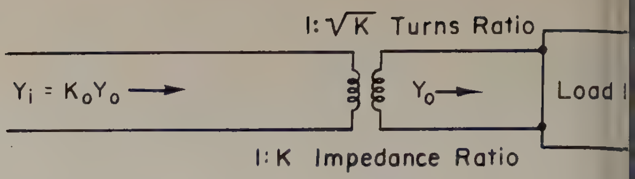

Figure 8 — Equivalent circuit of transformation $Y_i = K_oY_o$

which implies that the transformation (6) becomes

$$\frac{I_i}{V_i} = \frac{d}{a} \frac{I_o}{V_o} \tag{29}$$

or

$$Y_i = K_oY_o \tag{30}$$

and

$$Z_i = \frac{Z_o}{K_o} \tag{31}$$

which suggests the equivalent circuit of Figure 8.

BIBLIOGRAPHY

1. Deschamps, G. A., "Determination of the Reflection Coefficients and the Insertion Loss of a Wave-Guide Junction," Federal Telecommunications Laboratory Report 1347, December 1951.
2. Storer, J. E., Sheingold, L. S., and Stein, S., "A Simple Graphical Analysis of a Two-Part Waveguide Junction," Proc. of I.R.E., August 1953, Vol. 41, pp. 1005-1013.
3. Peters, Leon, Jr., "On the Calibration of Impedance Measuring Equipment," Report 487-9, 15 June 1954, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Contract AF 18(600)-160 with Wright-Patterson Air Force Base, Ohio.
4. Weissfloch, A., "Anwendung des Transformer-satzes Über verlustlose Vierpolen auf die hinter einander Schaltung von Vierpolen," Hoch Freq. Tech. Elec. Akust., Vol. 61, pp. 19-28, January 1943.
5. Dawirs, H. N., Boehnker, C. H., and Garbacz, R. J., "A Simple Slotted-Line Method of Accurately Measuring Impedances Through an Unknown Transition Section," Repo 762-3, 31 December 1957, Antenna Laboratory, The Ohi State University Research Foundation; prepared under Contract with the Boeing Airplane Company, Seattle 24, Washington.
6. Boehnker, C. H., Dawirs, H. N., Garbacz, R. J., Sapp, E. R and Tulloss, W. S., "A Study of Reflections from Small Ste Discontinuities in Coaxial Transmission Lines," Report 914- 17 March 1959, Antenna Laboratory, The Ohio State Unive sity Research Foundation; prepared under Contract with th Boeing Airplane Company, Seattle 24, Washington.
7. Dawirs, H. N. and Tulloss, W. S., "Determination of th Characteristic Impedance of Uniform Transmission Lines, Report 914-2, 31 July 1959, Antenna Laboratory, The Ohi State University Research Foundation; prepared under Contra with the Boeing Airplane Company, Seattle 24, Washington.
8. Collin, R. E., "Determination of Equivalent Circuit Parameters," I.R.E. Transactions, vol. MTT-5, p. 266, Octobe 1957.

* * *

ARCING IN CW TRANSMITTERS

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The problem of arcing in high peak power transmitters
a phenomenon familiar to all engineers in the radar field.
he high power of pulsed radars produces voltage gradients
ross the narrow dimensions of waveguide which exceed
e dielectric strength of the transmission medium. Break-
wn initiated by high voltage gradients, if not completely
derstood, is well appreciated by those concerned with
veguide component design.[1] Eliminating sharp corners,
essurizing with air, or substituting a gas with a higher
electric strength than air are some of the commonly
cepted techniques used to eliminate the arcing phenome-
n.

Prior to the operation of a high power X-band CW
nsmitter at Raytheon's Missile and Space Division, in-
rmation had been received from several organizations
erating such transmitters, indicating that unexpected
cing of the waveguide occurred.[2,3,4] Investigation into
ese reports did confirm the presence of arcs at random
casions, but since the power levels used showed little
rrelation to peak powers at which waveguide break-
wn should occur, an investigation into the cause of
e phenomenon was deferred until actual operation of a
gh power system was begun.

The CW arcing phenomenon is strongly dependent on
veguide power. Transmitters in the hundred watt range
e operating under field conditions with no reports of
ilure due to arcing. Initial experience with higher CW
wers was gained at the 1 KW level. Operation over a
riod of several months with several hundred hours of
eration was free of any arcing. No particular atten-
n was paid to waveguide finish, cleanliness, or con-
nsed water vapor.

A power increase to over 2 KW produced consistent
veguide arcing, in some cases after several hours' oper-
ion. The arcs appeared as a conducting discharge, dis-
pating typically 75% of the incident power and often occurring after prolonged periods of troublefree operation.

The arcing problem was approached from an engineering direction, for which a solution to the problem of protecting the tube and waveguide components from destruction was the important criterion. Manufacturing an arc at will was the first important step in designing a safety device followed by a study of the causes of such arcs. In the center of the broad wall of the guide, a stainless steel screw projecting a small distance equivalent to a VSWR of 1.2 consistently produced arcs. The lossy stainless steel would glow red immediately upon penetration into the guide. A sequence of the forming of an arc by means of a stain-

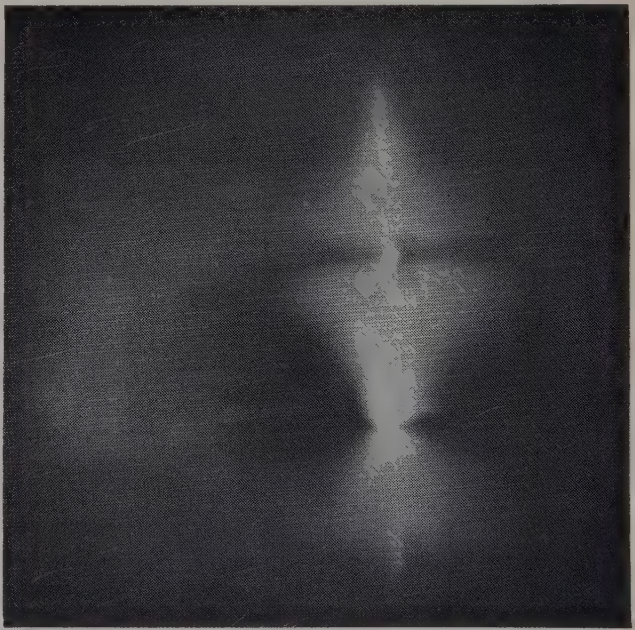


Figure 1 — Arc formation at inserted lossy screw.

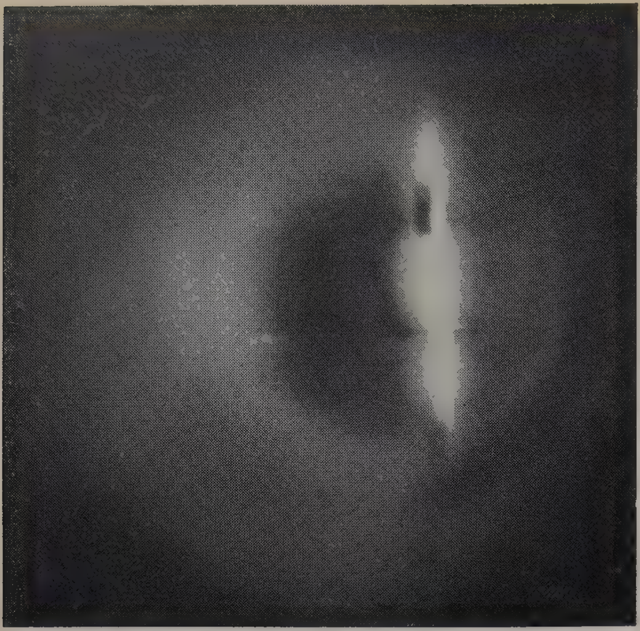


Figure 2 — Fully formed arc showing motion towards RF source.

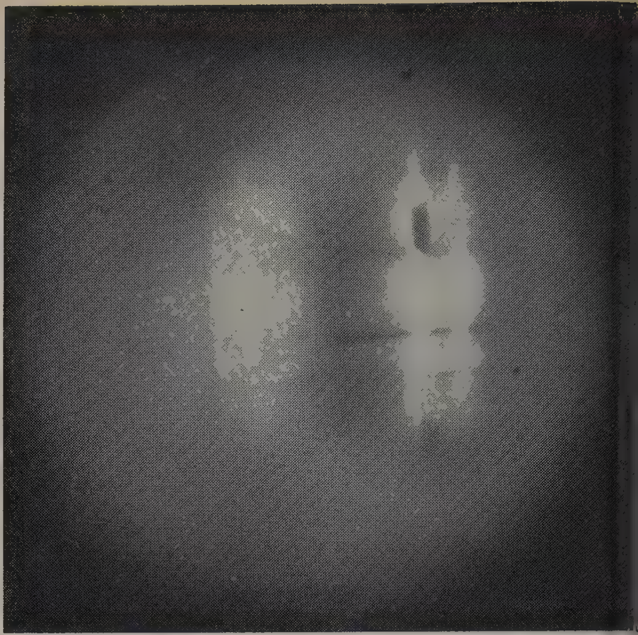


Figure 4 — Arc arrested at ceramic window showing doub arc at interface.

less steel screw is shown in Figures 1 through 4. The intense localized heat of a lossy metallic screw gave some insight into one of the possible causes of an arc.

Inspection of the frames revealed that the intense heat at the screw causes an ionized cloud to form, followed by small streamer discharges before the arc became completely formed across the guide. Measurement of the transmitted and reflected power revealed that approximately 75% of the power is absorbed in the arc with the remainder being reflected. This absorption factor of the arc is variable, and is dependent on power level, waveguide size, and temperature and pressure within the guide. Once struck across the guide, the arc moved toward the microwave power source at a velocity of, typically, 10 ft/sec. The d pendence of this velocity upon power is shown in Figu 6. When the arc impinged on a dielectric window, eith the tube seal or a pressure seal in the guide, it would co tinue to dissipate the energy until the seal was puncture An arc burning at such a ceramic window is shown Figures 4 and 5.

Note the splitting of the arc at the window caused b the higher order mode configuration at the air-ceram interface. Two views of this ceramic window after e posure to the arc for approximately one minute are show in Figures 7 and 8.

The object of the first phase of the study was to dete

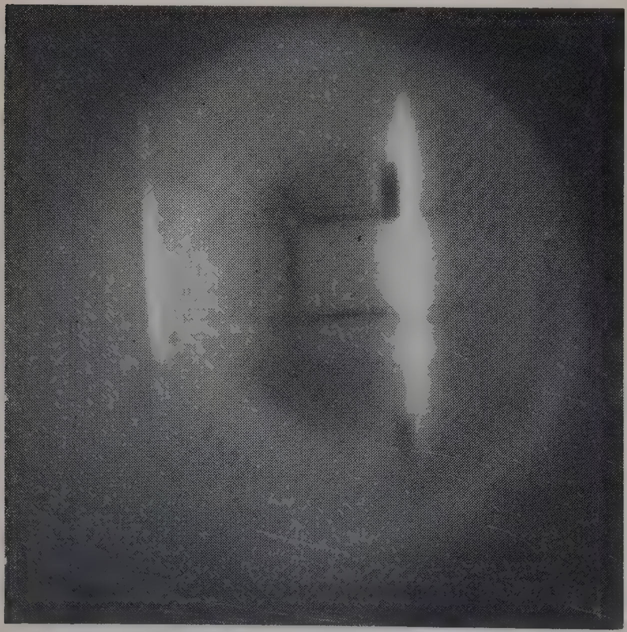


Figure 3 — Arc situated between initiating screw and ceramic half-wave window.

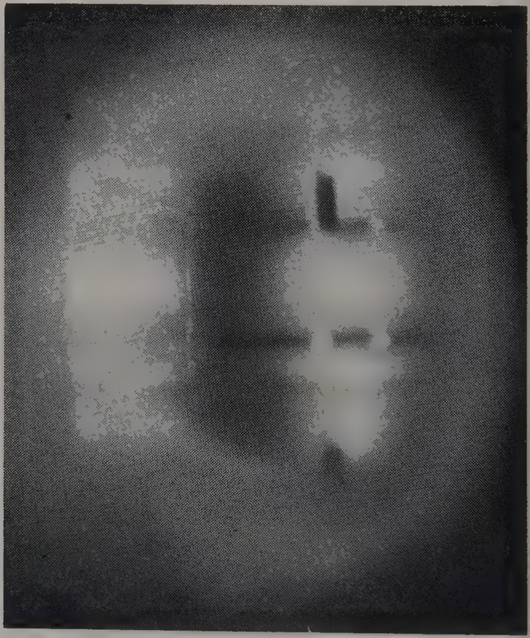


Figure 5 — Ceramic window at white heat after several se onds exposure to arc.

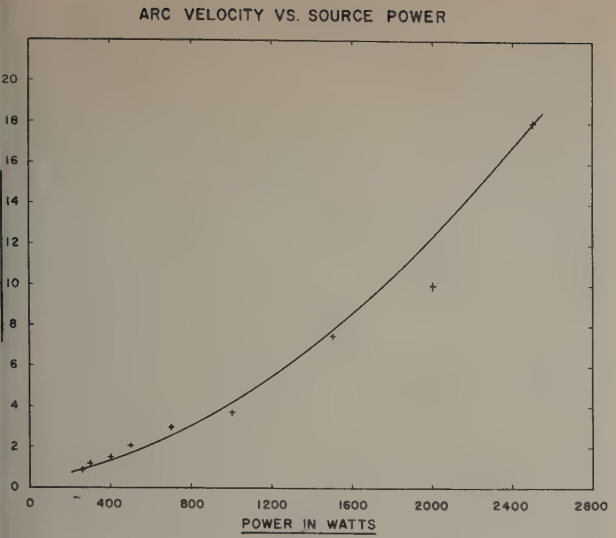
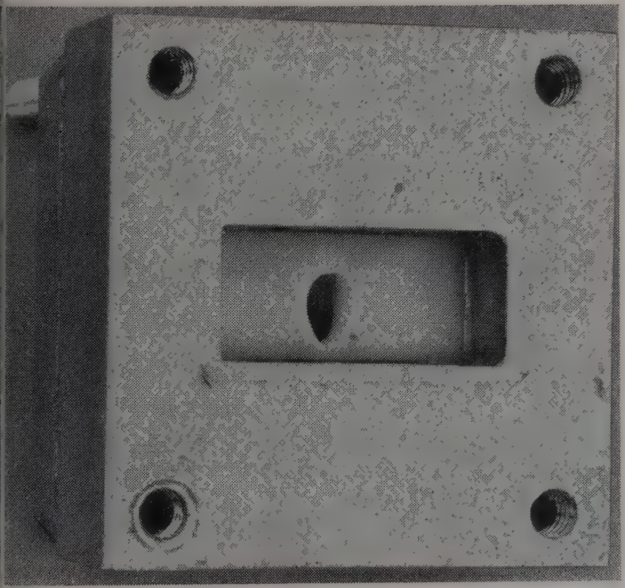


Figure 6

ine the characteristics of an arc which had been inten- onally created in a waveguide by insertion of a lossy ainless steel screw; also, to determine the mechanism of c formation and the effect of such an arc on various aveguide finishes and microwave components. Atten- on was also turned toward an investigation of the uses of such breakdowns in radar transmitter wave- uides. In general, the rapid movement of the formed arc manifested by a slight tarnishing of the waveguide etal. Ferrite devices have not been damaged by the pas- ge of an arc because of the high arc velocity.

The first attack was to introduce particles of foreign aterial into the waveguide to determine if an arc could e formed by the presence of such particles and to learn hat materials were most conducive to arc formation. It as found that materials such as neoprene rubber, residue ft after removing masking tape, or many other common aterials which might accidentally be introduced into aveguide would create an arc if they were sufficiently ssy, and if they contained carbon or other materials which would allow heating to orange or white heat. This degree of heating seemed to be necessary for the formation of an arc, since at several times particles glowing at a dull red heat would remain in the waveguide for long periods of time without initiating a breakdown.



igure 7 — Condition of ceramic window after several seconds exposure to arc.

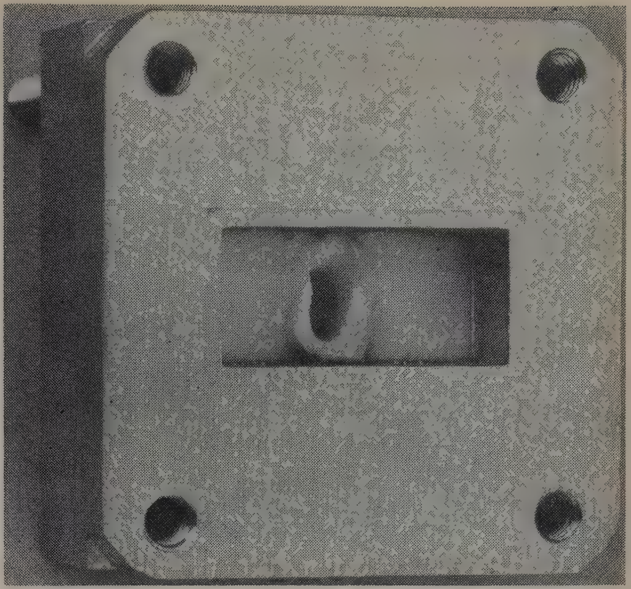


Figure 8 — Condition of ceramic window after several seconds exposure to arc.

Figure 9 shows a section of waveguide after an arc had occurred at the flange. Screws at this flange were not adequately tightened allowing leakage of sufficient energy to cause high local heating of the "0" ring and the subsequent breakdown of the guide.

Since the formation of an arc by means of foreign materials in the waveguide seemed so common, efforts were then made to determine how, even in the presence of such foreign particles, the formation of an arc could be prevented. Among those methods tried were: pressurization of the waveguide with air; pressurization of the waveguide with inert gas; filling of the waveguide at atmospheric pressure and under greater than atmospheric pressure with a high dielectric strength gas such as sulfur-hexafluoride,[5,6] and also blowing air through the waveguide at velocities of 5 to 10 feet per second in an attempt to sweep away any ionized concentrations formed and also to cause a cooling effect on any areas which might be subjected to high local heating.

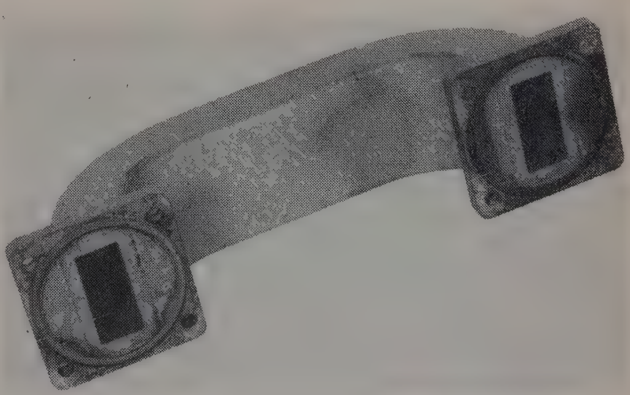


Figure 9 — Effects of arcing at loose flange.

It was found that under conditions of high temperature in the waveguide, the use of sulfur-hexafluoride had doubtful practicality. While the presence of this gas inhibited arcs to a great extent, it was found that any particle at red heat would cause dissociation of the sulfur-hexafluoride, liberating free fluorine which combined rapidly with the waveguide metal. If the red heat were caused by chipped or broken ferrite, the SF6 would decompose and reduce the ferrite to a fluorine salt. Arcs could be eliminated by use of SF6, but only by sacrificing the entire waveguide system.

The simplest of the methods tried was pressurization with dry air under excess pressure of approximately one atmosphere. The results indicated that higher power might be transmitted under these conditions than that which would normally break the waveguide down. It was decided, however, that the most practical method of preventing arc breakdown of waveguides at high CW powers would be through the practicing of cleanliness and proper surface treatment of the waveguide to insure that no foreign particles were introduced. It was also found that the use of efficient arc protection devices which would, upon sensing the formation of an arc, shut the transmitter power off for a period of 25 to 50 milliseconds could burn any foreign particle out of the waveguide by allowing it to arc repeatedly until all of the lossy components had been burned from the material.

A diagram of such an arc protection system is shown in Figure 10. The reaction time of this device was in excess of 200 μsec. Although measurements of rate-of-change of reflected power behind an arc indicated an average of 50 to 60 μsec for arc formation time, the arc sensing system was made to have quite a slow response time to allow each arc to partially consume the particle of foreign matter causing breakdown.

This arc quenching system gave complete protection from the destructive effect of arcs as long as a thick (λ/2) ceramic window was used immediately in front of the thin output window of the klystron amplifier. Previous to the incorporation of the thick protective window, several tubes had suffered cracked output windows in spite of proper operation of the arc detection circuits. Experimental investigation gave evidence of a shock wave generated by the arc and propagated down the wavegu striking the window. The tube manufacturer has sub quently incorporated a heavier output window in this stron.

One theory held that a major arc across the wavegu might develop from a small micro-arc present at a fla junction or other small discontinuity in the wavegu structure. In this investigation, a flange in a wavegu carrying several kilowatts was opened and the surf drawn approximately 1/4 inch apart. Although a lit "circle of fire" was formed around the interior of waveguide, causing heating of the joint sufficient to the brazing, together with the liberation of great quanti of smoke and fumes which might be thought to enha the formation of an arc; no arc transfer was seen from flange to create a major arc in the waveguide itself.

It was found that while the introduction of metal pa cles into the waveguide might cause an arc at the they were falling through the guide; once inside and ly closely against the waveguide wall they would not ca breakdown. However, an arc could be formed by sim tapping the waveguide with a hammer or other ins ment at the location of the metal particles, causing th to be shaken into the electric field, heated, and thus as an arc source.

The only materials which could be introduced i the waveguide with immunity from arcing were such terials as teflon, teflon-silicon compounds, and any o material which combined low loss and high temperat characteristics.

Such materials as polyethlyene, while not exceedin lossy, will quickly melt when introduced into the wa guide and will burn and create a waveguide arc.

Severe local heating over appreciable areas was found to contribute to waveguide arcing. The applicat of a blow torch to a small area of the waveguide wall sulting in a high temperature approaching dull red not result in a waveguide arc.

Conclusion

Prevention of waveguide arcing at high CW levels quires that extreme care be exercised to eliminate

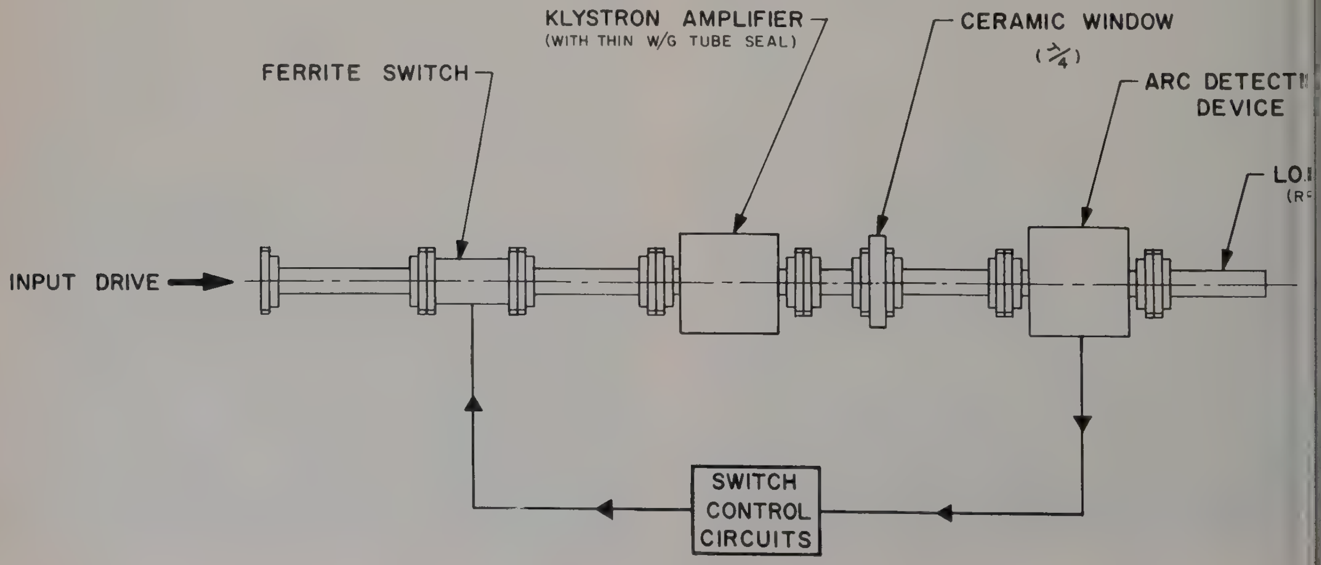


Figure 10 — Arc protection system.

foreign matter from the waveguide structure. The introduction of small pieces of rubber from the commonly used "0" ring pressure seal or bits of masking tape used to cover open waveguide will cause arcing immediately upon application of power. Metal chips, while usually not a problem under laboratory conditions, can become troublesome in vibrational environments. For efficient arc-producing materials, only small bits of material are required; a 1/64" square chip of "0" ring material will be sufficient to cause an arc.

In addition to the direct destructive energy of the arc, there are indications that a shock wave is formed when the arc strikes across the guide. In a prototype transmitter, the thin ceramic windows of several tubes were cracked when arcs were formed several feet behind a ferrite isolator. The protective circuits employed operated satisfactorily in all cases, but operated only after the arc had struck. In the arc-forming tests, the section of guide where arcs were struck had been separated from the tube by a half-wavelength dielectric window; no window cracking was ever encountered. An uncalibrated display of pressure on an oscilloscope showed a high pressure curve followed by a damped sinusoid due to internal reflections in the waveguide structure. The problem of window cracking was solved by inserting a half-wavelength dielectric window close to the tube.

The results of this study, while not providing a theoretical understanding or a comprehensive study of the observed effects of the CW arcing phenomenon, if applied in conjunction with satisfactory arc-detecting circuits can eliminate the destructive effects of arcs and allow uninterrupted system operation.

Acknowledgment

Much of the experimental investigation of this program was carried out by Mr. A. A. Black, and Mr. R. Mangiapane, of Raytheon's Missile & Space Division, Bedford, Massachusetts, and much appreciation is due them for their important contributions and suggestions in this study.

The investigation outlined herein was carried as part of an Army Ordnance Contract in the Radar Systems Department of the Missile and Space Division, Raytheon Company, Bedford, Massachusetts.

Bibliography

1. Barlow, H. M. *The Relative Power Carrying Capacity of High Frequency Waveguides,* Proc. I.R.E. 99, Pt. III, 21, 1952.
2. Discussions with John Clare, The Royal Radar Establishment, Malvern, England; September 1959.
3. Discussions with R. Adams, Ferranti Ltd. Edinburgh, Scotland; Sept. 1959.
4. Conferences and Experimental Data; Equipment Operations Division, Raytheon Company, Maynard, Mass. 1958-1959.
5. Arams, Freundlick and Peyser. *Final Report on Use of Sulfur Hexafluoride as a Microwave Dielectric,* RADC Report No 3276-1 Oct. 1957, Astia Document No. AD-131334.
6. Anderson, Reeves, Mears, Orfeo. *The Use of Sulfur Hexafluoride in Waveguides,* Dec. 1956, AIEE Conference Paper CP-57-82.

* * *

Determination of Maximum Insertion Loss Error Due to Mismatch

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In a microwave set up of two or more individual networks it is sometimes impossible, due to available power or equipment sensitivity, to measure the insertion loss of the entire assembly as a unit. However, the measurement of the individual networks presents no problem. Also, when the insertion loss of a network is measured, the power source is usually not the same source that is used for normal operation of the network. In both of these cases there is an error introduced into the measurement due to mismatch.

Consider two networks that have a known true insertion loss of A db and B db. If these two networks are to be used as one assembly, there will be an additional insertion loss due to the mismatch between them.

Using the measured insertion loss of the individual assemblies and the measured VSWR of each assembly, looked at from the common junction, the total maximum error of measurement can be determined.

Let the insertion losses be tabulated A db and B db and the associated voltage standing wave ratios as $VSWR_A$ and $VSWR_B$. It can be shown[1] that the measured ins tion loss of the whole assembly may be in error by a fact not greater than E, where $E = 20 \log_{10} (1 \pm \Gamma_A \Gamma_B)$ db a where Γ is the reflection coefficient corresponding to t VSWRs. When the VSWRs are known the error measurement E can be obtained from the nomogram

In a system of many mismatched assemblies havi known insertion losses of A db, B db, C db etc., a having individual junction errors E_1, E_2, E_3, etc., t total measured insertion loss and accompanying possi error is expressed as:

$$T_{db} = (A\text{ db} + B\text{ db} + C\text{ db} + \text{etc.}) \pm \sqrt{E_1^2 + E_2^2 + E_3^2 + \text{etc.}^2}, \text{ db}$$

where the errors are summed on an RSS basis.

When a source is interchanged in the system for purpose of measurements, the VSWR looking into two sources along with the nomogram can determine maximum error of measurement.

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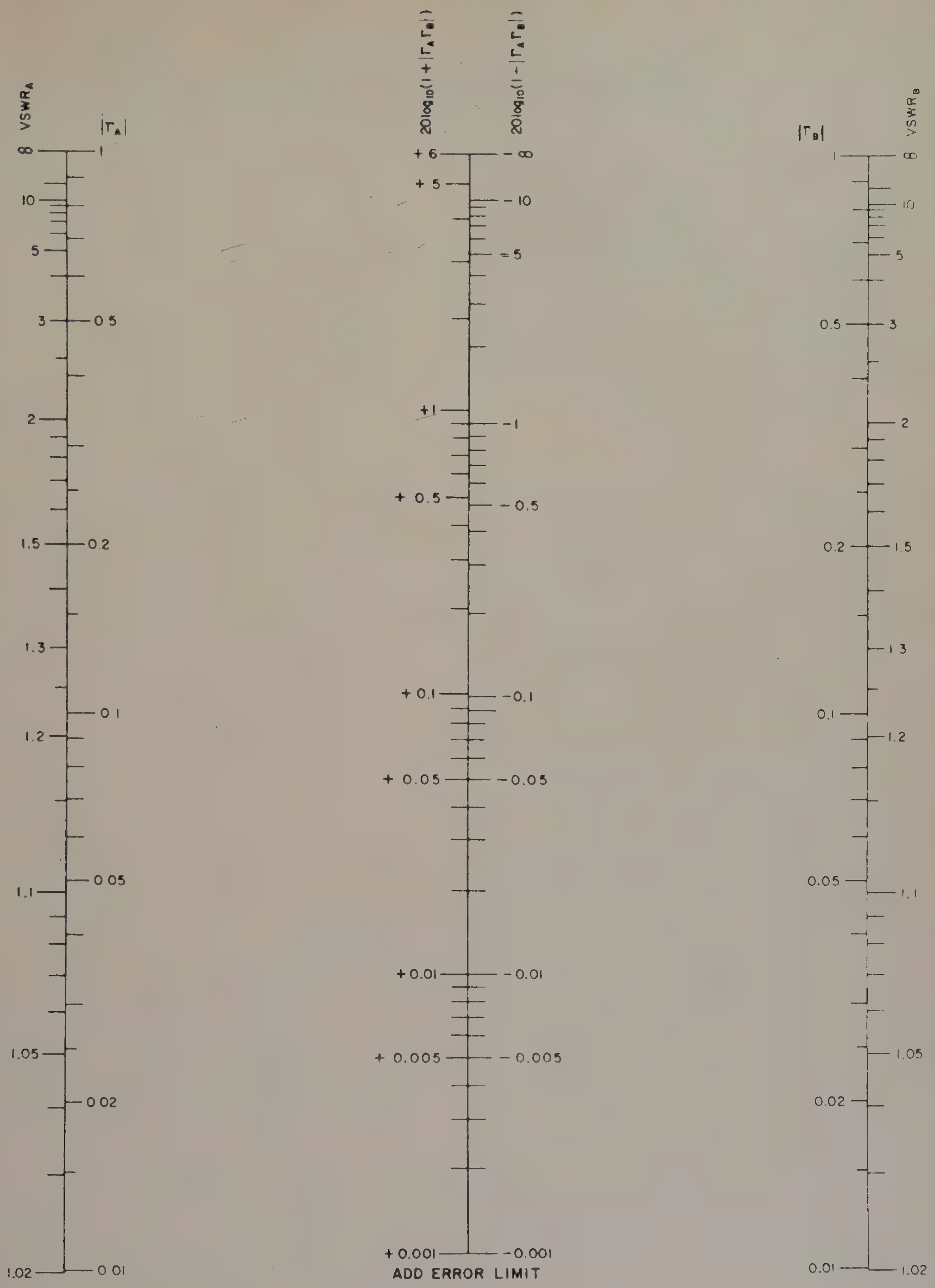
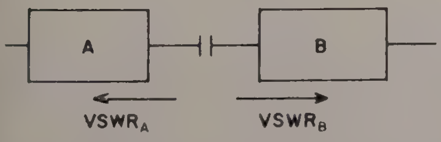
[1] *Microwave Attenuation Measurements, Report Number 1, Vol. Polytechnic Research and Development Company.*

NOMOGRAM OF MISMATCH ERROR LIMITS




A
B
VSWR$_A$
VSWR$_B$

TOTAL INSERTION LOSS = $(A+B)+20\log_{10}(1\pm|\Gamma_A\Gamma_B|)$ db.

CONCERNING HYBRIDS

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In all but the simplest of RF circuits the class of circuit elements known as hybrids** plays a vital role. They make possible the large number of balanced circuit configurations found in modern RF systems, among which are single sideband modulators, balanced mixers, constant impedance filters, linear phase shifters, balanced duplexers, and monopulse comparators to name a few. It is perhaps not an exaggeration to claim that this group of circuits constitutes the most important class of RF circuit elements. The old familiar forms of microwave hybrid are the "magic tee," the "rat race" or ring hybrid, and the short slot coupler. There are, however, many other hybrid circuits, some of which are variations of the above circuits and others which are completely different structures. The imaginative components engineer has solved many problems by liberally mixing transmission line types, by distorting the prototype forms, and occasionally by applying basic knowledge to arrive at a different hybrid configuration. As a result of the intense activity in the microwave field following World War II, the number of physical configurations with the properties of hybrids has become large indeed. The following is an attempt to present a self-consistent set of rules for describing and classifying microwave hybrid circuits.

Hybrid Theory and Classification

The hybrid is a four port device which is closely related to the directional coupler. A great number of hybrids can best be described as 3 db directional couplers, but devices such as the "magic tee" and balun junction do not fit very well into this descriptive pattern. The ideal hybrid(19) has perfect match and infinite directivity and may be described by the scattering matrix:

$$S = \begin{bmatrix} 0 & H \\ H_T & 0 \end{bmatrix}$$

where H is a submatrix of S and H_T is the transpose H. There are two permissible forms of H.

$$H\pi = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -1 & 1 \end{bmatrix}$$

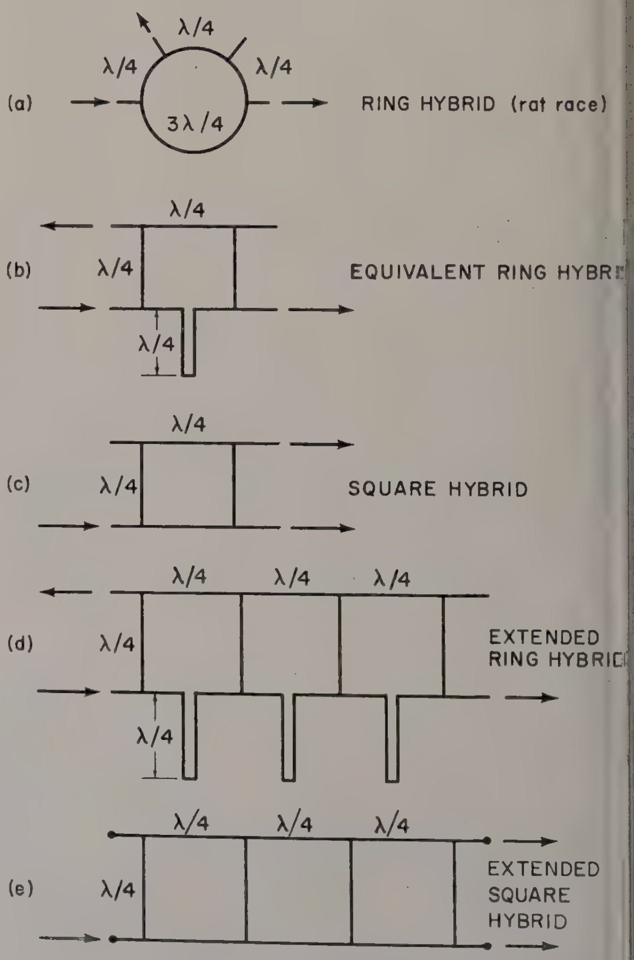

Figure 1 — Comparison of the ring hybrid and square hybr

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* *Operated with support from the U. S. Army, Navy, and Air Force.*

** *Superscripts refer to an extensive appended bibliography.*

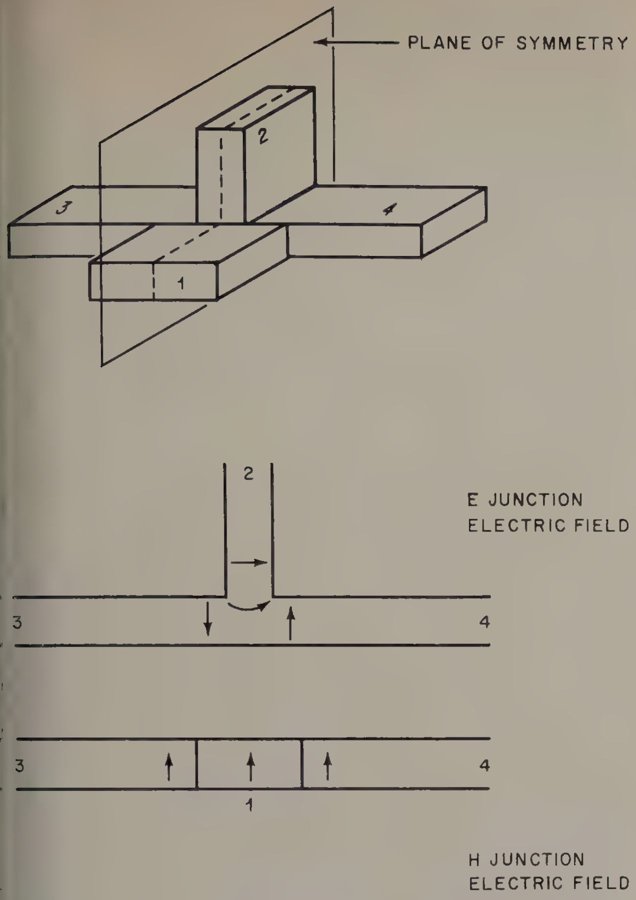

Figure 2a — The "magic tee," a symmetrically fed hybrid.

$$H\pi/_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & j \\ j & 1 \end{bmatrix}$$

These scattering matrix forms result from symmetry considerations. The first expression designated Hπ represents a device which has a single non-trivial plane of symmetry as is the case for the "magic tee," balun junction and "rat race." Most devices based upon directional coupler designs have two planes of symmetry and are represented by the matrix H$\pi/_2$. The hybrids in the Hπ category are characterized by a π phase difference between their output ports when fed at a single input. It is this particular characteristic which makes the "magic tee" in one of its many forms an ideal circuit element for use in the conventional monopulse comparator. Hybrids are thus divided into two general groups on the basis of symmetry, but this simple division is not adequate by itself as a means of classification. Many hybrid characteristics related to their non-ideal behavior such as the coupling and directivity bandwidths are determined by the nature of the coupling elements which tie their four terminals together. These considerations lead to the establishment of three distinct categories as follows:

(1) Symmetrically fed circuits
(2) Arrays
(3) Distributed parameter circuits

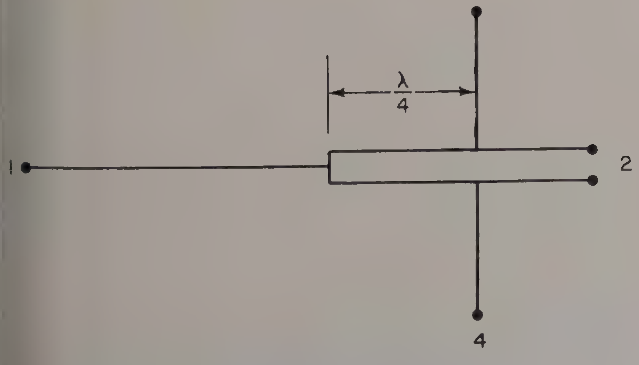

Figure 2b — Schematic of the balun junction.

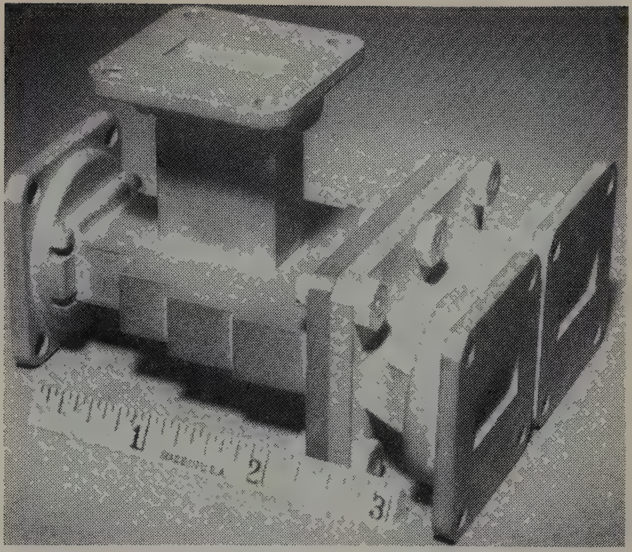

Figure 2c — Folded magic tee.

These three groups are natural ones which seem to accept all possible forms of hybrid circuits without redundancy. The lumped constant circuits have been excluded, but perhaps they should form a fourth category, thus completely describing this very interesting array of circuit elements.

The choice of circuit categories for hybrids is made difficult because there are many terms which are quite descriptive of groups of devices, but which for one reason or another, are found inadequate upon close scrutiny. For example, the terms "forward coupling" and "backward coupling" are in certain cases quite descriptive but cannot be applied to the "magic tee" and balun junction, nor is the forward or backward coupling characteristic always unique. Consider the arrays of Figure 1 where the direction of coupling can be controlled by phasing in the same manner as one controls the direction of radiation in the case of an antenna array.

Symmetrically Fed Circuits

The symmetrically fed circuits have a single plane of symmetry which passes through the two principal input ports, Figure 2. The various "magic tees" and balun junctions fall into this group. All are represented by the Hπ matrix, are sometimes referred to as π hybrids, and have the following properties.

(1) The power split ratio, i.e. the ratio of power out the two side arms when fed at one of the principal arms, is unity and is independent of frequency within the transmission line bandwidth.

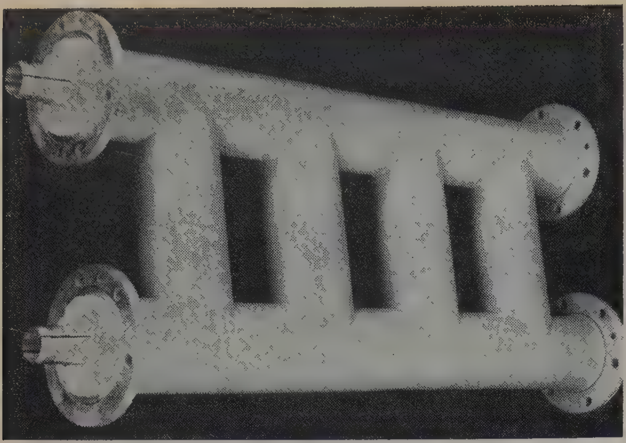

Figure 3 — Array hybrid in 3-1/8″ line.

(2) The directivity, when fed at one of the principal arms, is independent of frequency and can be made extremely high by carefully preserving the physical symmetry when the device is fabricated.

(3) The power split ratio and the directivity are independent of the match seen looking into the principal arms, provided symmetry is maintained.

The characteristics listed above, particularly the ability to achieve broadband directivity, make the symmetrically fed hybrids very useful devices for instrumentation purposes and they are often used as the principal elements of RF bridges. The balun junction can be adapted to printed circuit techniques and is useful when miniaturization is required.

Arrays

Hybrid circuits which fall under the classification of "arrays" are a special case of directional couplers which have discrete coupling elements and are closely related to linear antenna arrays. This class does not include such devices as the short slot coupler which has a single directive aperture, but rather those which consist of two or more non-directive coupling elements so arranged th the entire array is directive. The familiar two ho directional coupler is perhaps the simplest and be known example of circuits of this type. Multiple elemen arrays having binomial or Tschebyscheff distribution ca be designed to have very wide bandwidths and any d sired degree of coupling, including the 3 db couplin necessary for hybrids. The familiar rat race and squa hybrid(19) may be considered arrays in the true sen and extended to many coupling elements (12), Figure Array hybrids can be constructed in both waveguide an coaxial line and can couple either forward or backwa depending upon the choice of parameters. Figure shows a hybrid in 3 1/8 coaxial line which has nearly 30 per cent bandwidth at UHF measured to the 0.25 d unbalance. Coaxial designs are adaptable to printed ci cuit techniques for low power applications(3)(16).

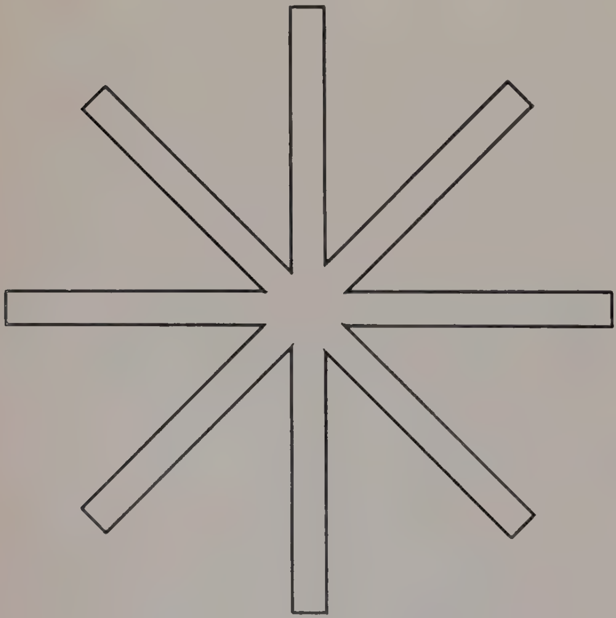

Figure 4 — Crossed slot coupling element.

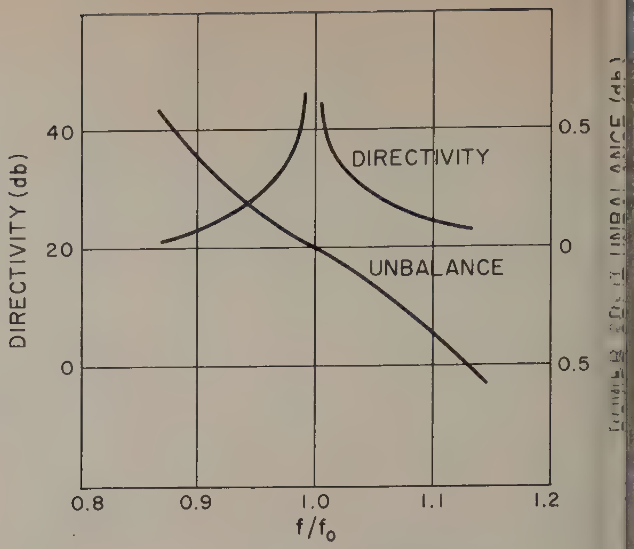

Figure 5 — Typical characteristics of coincident array of fo magnetic dipoles, a ring hybrid.

In addition to the circuits which are obviously array certain single hole couplers, such as the Bethe hole co pler, can be considered as arrays. This coupler is ma up of coincident electric and magnetic dipoles. In th case of the crossed slot coupler, Figure 4, the couplin elements are coincident magnetic dipoles. These typ of coupling elements usually provide weak coupling that an array of several elements is required for hybr applications. Although the individual apertures are d rective, it is not clear that an array of these directive el ments will produce better results than can be obtaine using comparable arrays of non-directive coupling ape tures.

It should be noted that certain devices falling in th category of arrays have a single plane of symmetry an consequently properties of π hybrids, for example th ring hybrid. These devices do not have the plane of sym metry passing through one or more of the input port however, and for this reason have less ideal behavi than the "magic tee" from the standpoint of constan of the power split ratio and the degree of directivi which can be obtained over a large bandwidth, Figure

Distributed Parameter Circuits

The term "distributed parameter" refers to those ci cuits in which two transmission systems are coupled t

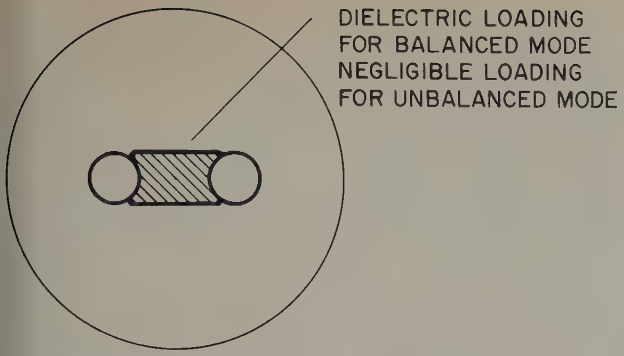

Figure 6 — Cross section of a TEM matched mode hybrid.

gether in a continuous fashion resulting in a circuit which has hybrid characteristics. Of these circuits, the short slot coupler is perhaps the most widely used and most familiar. In an idealized sense, the hybrids of this group can be considered to consist of two component parts: (1) the transition sections, of which there are two, one at each end of the hybrid, and (2) a section of uniform transmission line separating the two transitions. In actual hybrids there may be lumped compensating elements in the transmission line section which cause the circuits to depart somewhat from the above description. There are two distinct kinds of hybrid circuits which fit the above description. (1) Circuits in which the normal modes of the transmission section are matched at the transitions, and (2) circuits in which the normal modes are not matched. An example of the first group is the short slot coupler and of the second, the parallel line coaxial hybrid.

Matched Normal Modes

For the case where the normal modes are matched, the transitions are adjusted to excite the proper amplitudes for the required modes. The uniform transmission line is adjusted in length so that one mode group is advanced or retarded by 90 electrical degrees with respect to the other. This is accomplished as a result of the difference in the phase velocities of the two mode groups. In the case where both modes are TEM modes as might occur in a coaxial system, it is necessary to "load" one of the modes so that it will be delayed, Figure 6, since all TEM modes travel at the same velocity in a uniform medium. The output voltage ratios for circuits which match to the normal modes, assuming ideal mode launching transitions, varies as tan $\frac{1}{2}(\beta_1 - \beta_2)l$. β_1 and β_2 are the propagation factors for the two normal modes. The differential phase velocity places a limit on the useful bandwidth of these devices. The match and directivity of the coupling sections places an additional limitation on the device.

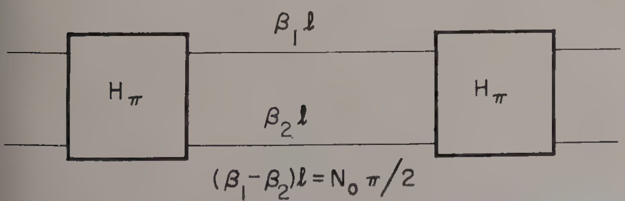

Figure 7 — Equivalent circuit of matched mode hybrids.

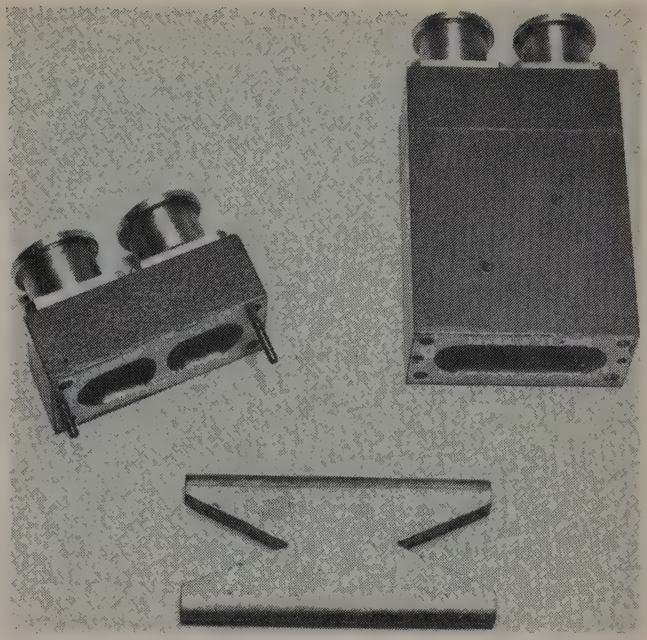

Figure 8 — The "cobrid," a matched mode hybrid.

The mode launcher is a four terminal device considering the uniform line as consisting of two lines, one for each mode group. Since the modes are matched at the launchers, the directivity of the hybrid depends on the directivity of the launcher. The launcher is therefore a hybrid in itself, having a single plane of symmetry. The pair of transitions, separated by the uniform line, produce a hybrid having two planes of symmetry. The equivalent circuit of these distributed hybrids is shown in Figure 7.

Among the hybrids which belong to the matched mode group are

(1) Short slot side wall; TE_{10}, TE_{20} modes.
(2) Top wall two slot; TE_{10}, TEM modes.
(3) "Cobrid" (coax equivalent of two slot top wall); TEM, TE_{12} (coaxial), Figure 8.
(4) Top wall single slot; TE_{10} and TE_{11}, TM_{11} degenerate pair.

Sometimes the directivity bandwidth and coupling bandwidth of a hybrid device can be improved in a limited fashion by means of lumped loading. This technique has been employed in the side wall short slot coupler as is evident in the photograph of Figure 9. Such techniques modify the phase velocity characteristics in such a way as to preserve a more nearly unity output voltage ratio over a wider band than would be attainable with a uniform line, and can be used to produce backward radia-

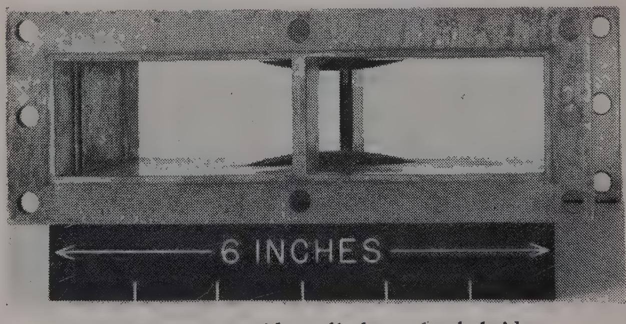

Figure 9a — Side wall short slot hybrid.

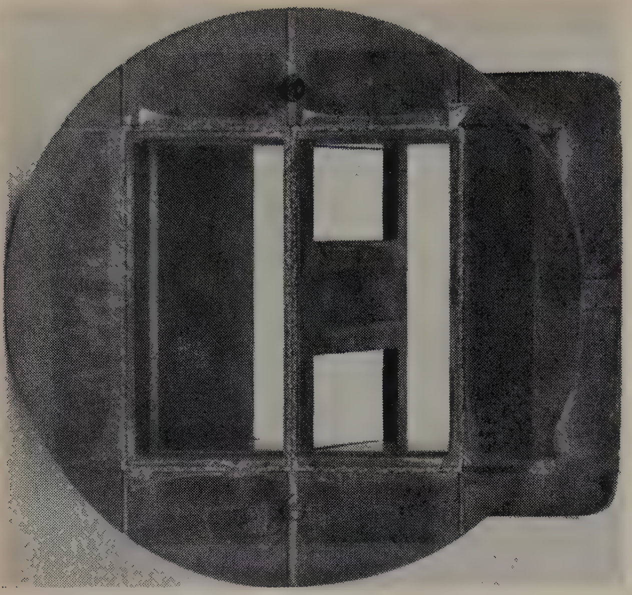

Figure 9b — Top wall coupler.

tion in the proper phase to overcome a poor directivity characteristic of a mode launcher over a limited frequency range.

Unmatched Normal Modes

In the second category of distributed parameter hybrids the transitions are not matched to the normal modes of the uniform transmission section and these transitions cannot be described as hybrids as in the case where the normal modes are matched. Perhaps the best example of the unmatched mode device is the coupled line hybrid of Figure 10. This circuit can take many forms and is often used in the form which consists of two lines between ground planes, arranged in such a fashion that they have mutual coupling for some portion of their length. "Loop" type directional couplers in waveguide systems are also examples of devices employing these same coupling principles. Here, however, the difference in phase velocity between the two coupled lines limits

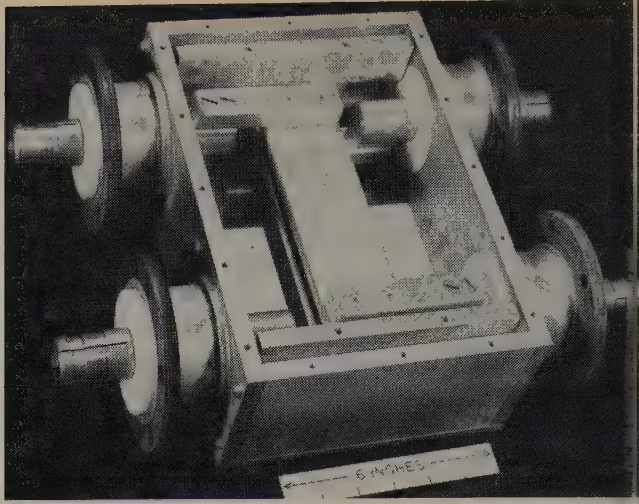

Figure 10a — Coupled coaxial line hybrid in 3-1/8″ line.

the directivity bandwidth. As far as is known, no practical 3 db coupler of this waveguide-coaxial configuration has ever been built.

The operation of the unmatched mode directional coupler has been described in various ways. One method considers the normal modes, having somehow been excited in the system, as being partially reflected at the transitions due to the impedance mismatch. The sum of the outgoing fields for n reflections is zero at the input and at the decoupled terminal. At the primary and secondary line output terminal, the sums of the fields accounts for all of the energy fed in at the input terminal. Under these conditions, it is readily seen that the device is matched and has infinite directivity, therefore being an ideal directional coupler(¹). Perhaps a better way of understanding these devices is to consider an incremental length of the uniform transmission system. It can be shown that this incremental length constitutes an ideal directional coupler. The total coupling is found by an integration method which sums the coupled fields along the transmission section, taking into account the coupling back onto the primary line. The directivity of the coupler is determined by the impedance match at the transitions, since any backward waves in the system will couple to the terminal which is decoupled for forward going waves. This approach is perhaps better than the normal mode approach from the standpoint of understanding the operation of the device. To solve a specific problem using this concept requires, however, the solution of boundary value problem with its inherent difficult integrations. By using the technique of superposition of the normal modes and well known transmission line theory, one can easily determine the necessary impedance relationships and account for the effect of the length of the interaction section.

For the case of uniform coupled lines the output voltage ratio is found to be K sin βl.

$$K = 1/2\left(k - \frac{1}{k}\right);\ \text{where } k = \frac{2Z_2}{R_o} = \frac{2R_o}{Z_1};\ k > 1$$

Z_1 and Z_2 are the impedances of the odd and even modes respectively and R_o is the impedance of the terminations, i.e., connecting lines. The simplest of these hybrids has a coupling section of length $\lambda_o/4$ with the coupling adjusted to be slightly tighter than 3 db at mid-band pro

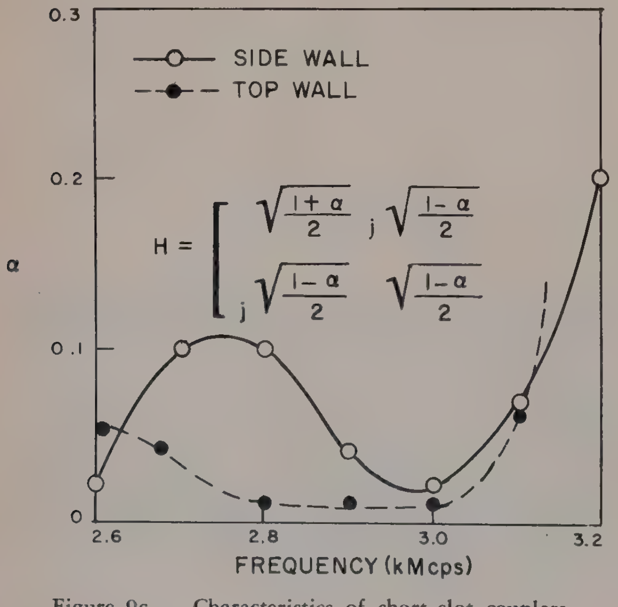

Figure 9c — Characteristics of short slot couplers.

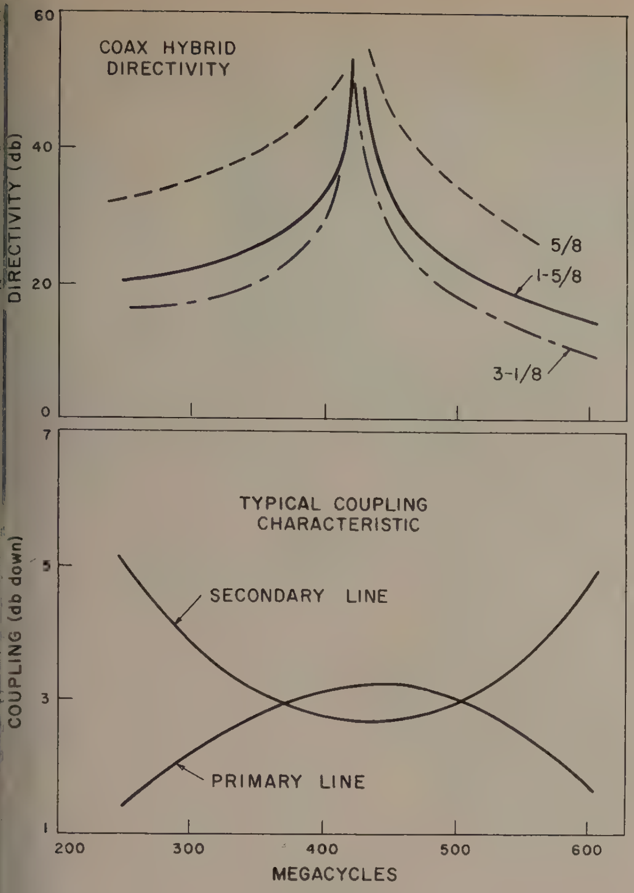

Figure 10b — Characteristics of coupled coaxial line hybrids.

viding two points of exactly 3 db coupling each side of the design frequency and a useful bandwidth of about 2:1 (ratio of highest to lowest frequency) depending on the deviation from 3 db which can be tolerated. Shimizu and Jones [13] have described a more elaborate hybrid of length 3λ/4 consisting of a non-uniform coupling section. Their device is comprised of three λ/4 coupling elements in cascade, the center coupling element differing from the two identical end couplers. The useful bandwidth of this 3λ/4 device is more than twice that obtainable with the simple λ/4 hybrid.

Summary

The foregoing description of hybrids has not specifically mentioned all of the RF circuits which have the properties of hybrids, and are indeed hybrids in the true sense. Among these circuits are polarizers such as the turnstile, and orthogonal mode transducers such as those used in Faraday rotators and in other applications. In all of these cases the junctions have a single plane of symmetry, and two sets of terminals must be assigned to the transmission line supporting the orthogonal modes. These circuits are matched mode hybrids and differ only in detail from the mode launchers used in short slot hybrids. Such circuits have various uses as in dual polarization antennas, phase shifters, and as variable couplers, and in at least one case as the principal element of a waveguide dual channel rotary joint(36). The applications for this versatile group of circuit elements appears to be unlimited.

There is such a wide variety of hybrids with such a large variation in their bandwidth and power handling capabilities that it does not seem possible to write a prescription which will result in a unique choice of components for any specific application. In practice, not only must the RF requirements be met, but also a set of physical requirements in order to achieve compatability with the required physical configuration of the entire RF assembly.

When power handling capability is the controlling requirement, the choice of components will be limited to those achievable in waveguide except at the lower frequencies where coaxial line becomes attractive because of its smaller physical size. When large bandwidths are required and physical size is not important, the multi-element array in waveguide can be designed to cover the useful waveguide bandwidth and at the same time handle large amounts of power. Even wider bandwidths can be achieved using the unmatched mode couplers in coaxial line with 2:1 bandwidth achievable with a simple λ/4 device and 4+:1 bandwidth achievable with a more complex $\frac{3\lambda}{4}$ circuit. (Here the definition of bandwidth is taken as the ratio of the highest or lowest frequency.) For the most part, these coaxial devices have a limited peak power handling capability as a result of the close spacings required in achieving the necessary impedance relationships. Such devices are, however, capable of handling considerable average power at low frequencies.

The matched mode devices, such as the short slot coupler, are capable of transmitting large peak power but have a fundamental bandwidth limitation placed upon them as a result of the differential phase velocity between the two mode groups. A 15 per cent bandwidth is achievable with waveguide circuits and satisfies most radar requirements since high power transmitter tubes of greater bandwidth are not available at present.

Among the π hybrids, the "magic tee" and balun junction are well known and widely used. The folded magic tee is capable of handling considerable power in its H-plane arm, but usually is somewhat power limited in its E-plane arm. Its usefulness in high power circuits is also limited by the ability to obtain a broadband match. The balun junction can be matched over a band as great as 3:1 and can handle considerable average power making it a very useful component for both coaxial line power applications and for low level printed circuit devices.

The fact that so many forms of hybrids have been invented is indicative of their importance in high frequency circuits. As the complexity of RF systems increases, the hybrid circuit will undoubtedly play an ever increasingly important role.

Bibliography

1. B. M. Oliver, "Directional Electromagnetic Couplers," Proc. IRE, Vol. 42, pp. 1686-1692, Nov. 1954.
2. E. M. T. Jones, J. T. Bolljahn, "Coupled-Strip-Transmission-Line Filters and Directional Couplers," Trans. IRE, Vol. MTT-4, pp. 75-81, April 1956.
3. Herbert G. Pascalar, "Strip Line Hybrid Junction," Trans. IRE, Vol. MTT-5, pp. 23-30, Jan. 1957.
4. A. Alford, "Coupled Networks in Radio-Frequency Circuits," Proc. IRE, Vol. 29, pp. 55-70, February 1941.

5. J. J. Karakash and D. E. Mode, "A Coupled Coaxial Transmission-Line Band-Pass Filter," Proc. IRE, Vol. 38, pp. 48-52, Jan. 1950.
6. W. L. Firestone, "Analysis of Transmission Line Directional Couplers," Proc. IRE, Vol. 42, pp. 1529-1538, October 1954.
7. R. C. Knechtli, "Further Analysis of Transmission-Line Directional Couplers," Proc. IRE, Vol. 43, pp. 867-869, July 1955.
8. V. J. Albanese and W. P. Peyser, "An Analysis of a Broad-Band Coaxial Hybrid Ring," Trans. IRE, Vol. MTT-6, pp. 369-373, October 1958.
9. W. A. Tyrell, "Hybrid Circuits for Microwaves," Proc. IRE, Vol. 35, pp. 1294-1306, November 1947.
10. W. V. Tyminski and A. E. Hylas, "A Wide-Band Hybrid Ring for UHF," Proc. IRE, Vol. 41, pp. 81-87, Jan. 1953.
11. T. Morita and L. S. Sheingold, "A Coaxial Magic T," Trans. IRE, Vol. MTT-1, pp. 17-23, November 1953.
12. J. Reed and G. J. Wheeler, "A Method of Analysis of Symmetrical Four-Port Networks," Trans. IRE, Vol. MTT-4, pp. 246-252, October 1956.
13. J. K. Shimisu and E. M. T. Jones, "Coupled Transmission-Line Directional Couplers," Trans. IRE, Vol. MTT-6, pp. 403-410, Oct. 1958.
14. E. F. Barnett, P. D. Lacy, and B. M. Oliver, "Principle of Directional Coupling in Reciprocal Systems," Proc. Sympos. Modern Advances in Microwave Techniques. Sponsored by Polytechnic Inst. of Brooklyn, Microwave Research Inst., Brooklyn, N. Y., Vol. 14, pp. 251-268, Nov. 1954.
15. G. D. Monteath, "Coupled Transmission Lines as Symmetrical Directional Couplers," Proc. IRE, London, Pt. B Vol. 102, pp. 383-392, May 1955.
16. J. K. Shimisu, "Strip-Line 3 db Directional Couplers," 1957 IRE Wescon Convention Record, Pt. 1, pp. 4-15.
17. F. Bolinder, "Approximate Theory of the Directional Coupler," Proc. IRE, Vol. 39, p. 291, March 1951.
18. R. F. Schwartz, "Bibliography on Directional Couplers," Trans. IRE, Vol. MTT-2, No. 2, pp. 58-63, July 1954.
19. C. G. Montgomery, "Principles of Microwave Circuits," Rad. Lab. Series, McGraw-Hill, Inc., New York, N. Y., Vol. 8.
20. H. J. Riblet, "A Mathematic Theory of Directional Couplers," Proc. IRE, Vol. 35, p. 1307, Nov. 1947.
21. N. I. Korman, "Theory and Design of Several Types Wave Selectors," National Electronics Conference, Oct. 1946.
22. W. W. Mumford, "Directional Couplers," Proc. IRE, Vo 35, pp. 160-166, Feb. 1947.
23. E. L. Ginston and P. S. Goodwin, "A Note on Coaxi Directional Couplers," Proc. IRE, Vol. 38, pp. 305-31 March, 1950.
24. H. C. Early, "A Wide Band Directional Coupler for Wav guide," Proc. IRE, Vol. 34, pp. 883-886, Nov. 1956.
25. H. J. Riblet and T. S. Saad, "A New Type of Waveguid Directional Coupler," Proc. IRE, Vol. 36, pp. 61-64, Ja 1948.
26. H. J. von Baeyer and R. C. Knechtli, "Uber die behandlun von Mehrleitersystemen mit term wellen bei hohen fr quenzen," Zeit. fur Angew, Math. and Phys. Vol. 3, pp 271-286, 1952.
27. A. Alford, "High-Frequency Bridge Circuits and High-Fre quency Repeaters," U. S. Patent 2,147,809, Feb. 21, 1939.
28. E. G. Fubini and P. J. Sutro, "A Wide-Band Transforme from an Unbalanced to a Balanced Line," Proc. IRE, Vo 35, pp. 1153-1155, October 1947.
29. Patricia A. Loth, "Recent Advances in Waveguide Hybri Junctions," Trans. IRE, Vol. MTT-4, pp. 268-271, Octobe 1956.
30. Clarence W. Jones, "Broad-Band Balanced Duplexers, Trans. IRE, Vol. MTT-5, pp. 4-12, January, 1957.
31. H. T. Budenbom, "Analysis and Performance of Wave guide-Hybrid Rings for Microwaves," Bell System Techn cal Journal, Vol. 27, pp. 473-486, July, 1948.
32. G. Saxon and C. W. Miller, "Magic Tee Waveguide Junc tion," Wireless Engineer, Vol. 25, No. 296, p. 47, Ma 1948.
33. W. A. Tyrrel, "Waveguide Hybrids," Bell Labs. Recor Vol. 26, p. 4, Jan. 1948.
34. H. J. Riblet, "Short Slot Hybrid Junction," Proc. IRE, Vo 40, pp. 180-184, Feb. 1952.
35. K. Tomiyasu and S. B. Cohn, "The Transvar Directiona Coupler," Proc. IRE, Vol. 41, pp. 922-926, July, 1953.
36. Ragan, "Microwave Transmission Circuits," Rad. Lab. Ser ies, Vol. 9, p. 428, McGraw-Hill, New York, 1948.

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(*Continued on page 109*)

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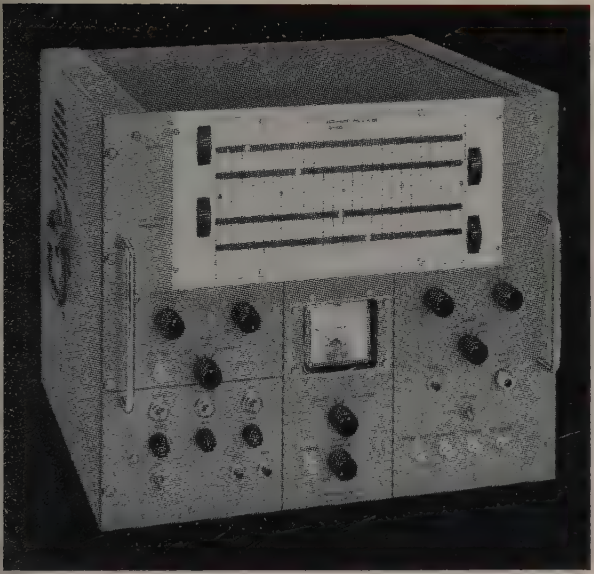

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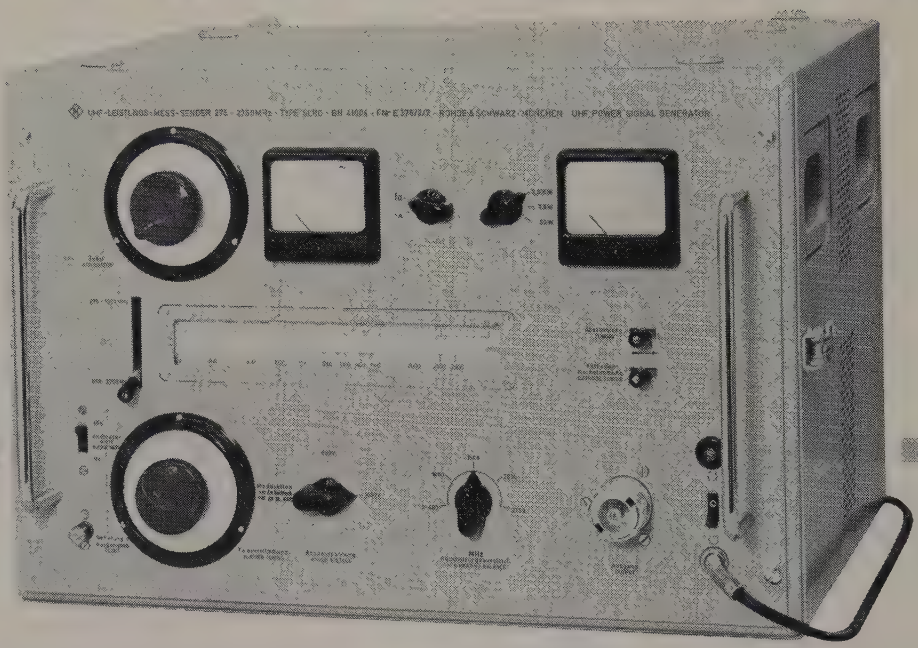

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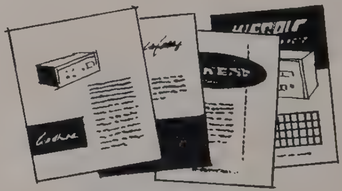

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(*Continued from page 106*)

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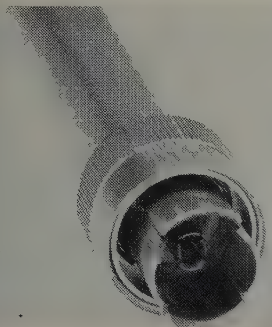


New versions of the familiar type 874 oaxial Connectors, including locking ca- le and panel and recessed locking panel ypes, have been announced by the Gen- ral Radio Co., West Concord, Mass.

Retaining the hermaphrodite feature f the standard 874's, the locking con- ector is fully compatible with the non- ocking types. VSWR is lower for both ocking and non-locking versions up to ight Gc, than the N, C, BNC and UHF ypes; also leakage is low for the locking ersion and higher voltages than former- y can be tolerated for both types.

Instruments equipped with the new ecessed-locking connectors can be fitted uickly with locking adaptors for a semi- ermanent conversion to other connector ystems, with a minimum of space added n front of the panel.

The type 874 Panel Connectors are vailable in four basic types, and lock- ng adaptors are now available to connect the type 874 to types BNC, C, N, C, TNC and UHF plugs. Also available re standard, non-locking adaptors for lugs and jacks of the types mentioned, lus types HN, LC, LT, UHF Rigid Line (EIA TR-134) and the 3/4 inch-spaced inding posts and jacks.

Circle Reader Service Card 107

—*mwj*—

BOMAC DEVELOPS THREE CRYSTAL PROTECTORS

Bomac Laboratories, Beverly, Mass., has developed three high-frequency crystal protectors to provide reliable protection from 16.0 to 70.75 kMc. The crystal protectors feature low leakage power and short recovery times over a wide range of incident power and ambient temperatures.

The BLS-513, at V-band, exhibits excellent protective characteristics over a wide temperature range. Frequency is 68.75 to 70.75 kMc, with 10 kW peak power at .0005 duty cycle. Insertion loss is 0.8 db maximum. Spike leakage energy at +85°C is less than 0.1 erg for peak powers to three kW. Recovery time at −55°C is 0.9 microseconds maximum.

At Ku-band, the BLS-523 gas switching crystal protector is only 0.45 inches long, less than half the length of a standard Ku-band TR tube. Weight is approximately two ounces. Frequency range is 16.0 to 17.0 kMc. Crystal protection is guaranteed from 0 to 10 kW peak power, at 0.0015 duty cycle. The tube can be operated efficiently over a temperature range from −55°C to +85°C, with a recovery time of 3.0 microseconds maximum.

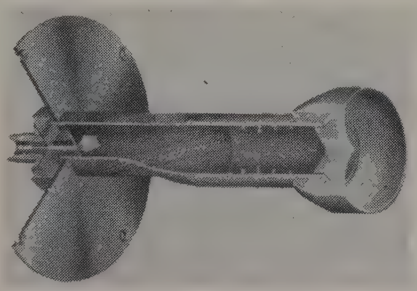
The third Bomac tube is a five-element Ka-band crystal protector, the BLT-058. It is designed to operate from 33.50 to 35.50 kMc. Power range is from 50 watts to 10 kW, at 0.0004 duty cycle. Operating temperature range is from −55°C to +125°C. The BLT-058 measures 0.476 by 1.5 by one inch, and weighs approximately one ounce.

Circle Reader Service Card 108

—*mwj*—

X-BAND LENS ANTENNA AVAILABLE FROM CANOGA

An X-Band Lens Antenna which radiates a circular polarization with a hemispherical radiation coverage is available from Canoga Electronics Corp., Van Nuys, Cal. Two lens antennas properly installed on an airborne vehicle afford complete tracking coverage for any yaw, pitch or roll aspect.



The model ALXN-1A consists of a type N connector, a coaxial to rectangular waveguide transition, a taper section from rectangular to circular waveguide, a section of circular waveguide containing a six-pin circular polarizer and four orthogonally placed matching posts. The circular waveguide is terminated in a dielectric lens. The lens broadens the beam to provide more nearly isotropic radiation over the hemisphere.

The ellipticity ratio is better than ±1.5 db over a hemisphere. In addition, the signal is constant within about ±2.4 db over the hemispherical coverage. Model ALXN-1A is also available with waveguide input. It has been Qualification Tested and meets MIL-E-5272.

Circle Reader Service Card 109

—*mwj*—

(*Continued on page 110*)

THIN DISCS

FAT RODS

. . . And, a variety of sizes and shapes in-between. THIN . . . from .0005″ crystal discs. FAT . . . up to 2.0″ diameter and 3.0″ long polycrystalline rods.

When you use MCL Garnets you can be certain of TOP performance. MCL Garnets are produced under optimum laboratory conditions and the resulting products are uniformly HIGH in quality. That is why leading manufacturers of microwave components are standardizing on MCL Garnets.

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Lincoln Laboratory is supplementing its staff. The Laboratory is engaged in basic air defense research for the space age. This expanding program is a natural outgrowth of our advanced research and development in the fields of Radio Physics, Radar, Systems Studies, Satellite Surveillance, Computer Technology and Solid State Physics. Senior scientists are invited to join the Laboratory in solving urgent problems of importance to the defense of the United States.

The Laboratory is seeking qualified specialists in:

RADIO PHYSICS and ASTRONOMY

NEW RADAR TECHNIQUES

SOLID STATE PHYSICS and METALLURGY

- *A more complete description of the Laboratory's work will be sent to you upon request.*

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Research and Development
LINCOLN LABORATORY
Massachusetts Institute of Technology
BOX 25
LEXINGTON 73, MASSACHUSETTS

New Products

(*Continued from page 109*)

GE DEVELOPS VOLTAGE-TUNAB MAGNETRON

A bowl-magnet design voltage-tunab magnetron has been developed by Ge eral Electric's Power Tube Dept., Sche ectady, N.Y.

The voltage-tunable magnetron, ty ZM-6021, covers the L-band in a rat range of 1 Gc — 2.3 Gc at a minimu CW power of one watt. It operates at maximum anode voltage of 2000 volts.

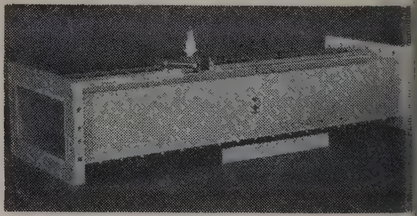
The ZM-6021 weighs three pounds an is a complete rf power source requiri only input power connections and an power output connection. It is volta tunable over all or a portion of its fr quency range at a rate of 1.2 Mc p volt.

The ZM-6021 can be used in a varie of existing equipment designs, includi all types of receivers that use an el tronically-swept local oscillator, t equipment, drivers for amplifiers, an output tubes that cover either part all of the L-band.

Circle Reader Service Card 110

— *m w j* —

ASI OFFERS SLOTTED LINES IN WAVEGUIDE SIZES WR-430 — WR-2300



Antenna Systems, Inc., Hinghar Mass., offers a complete line of slotte lines in all waveguide sizes from WI 430 through WR-2300.

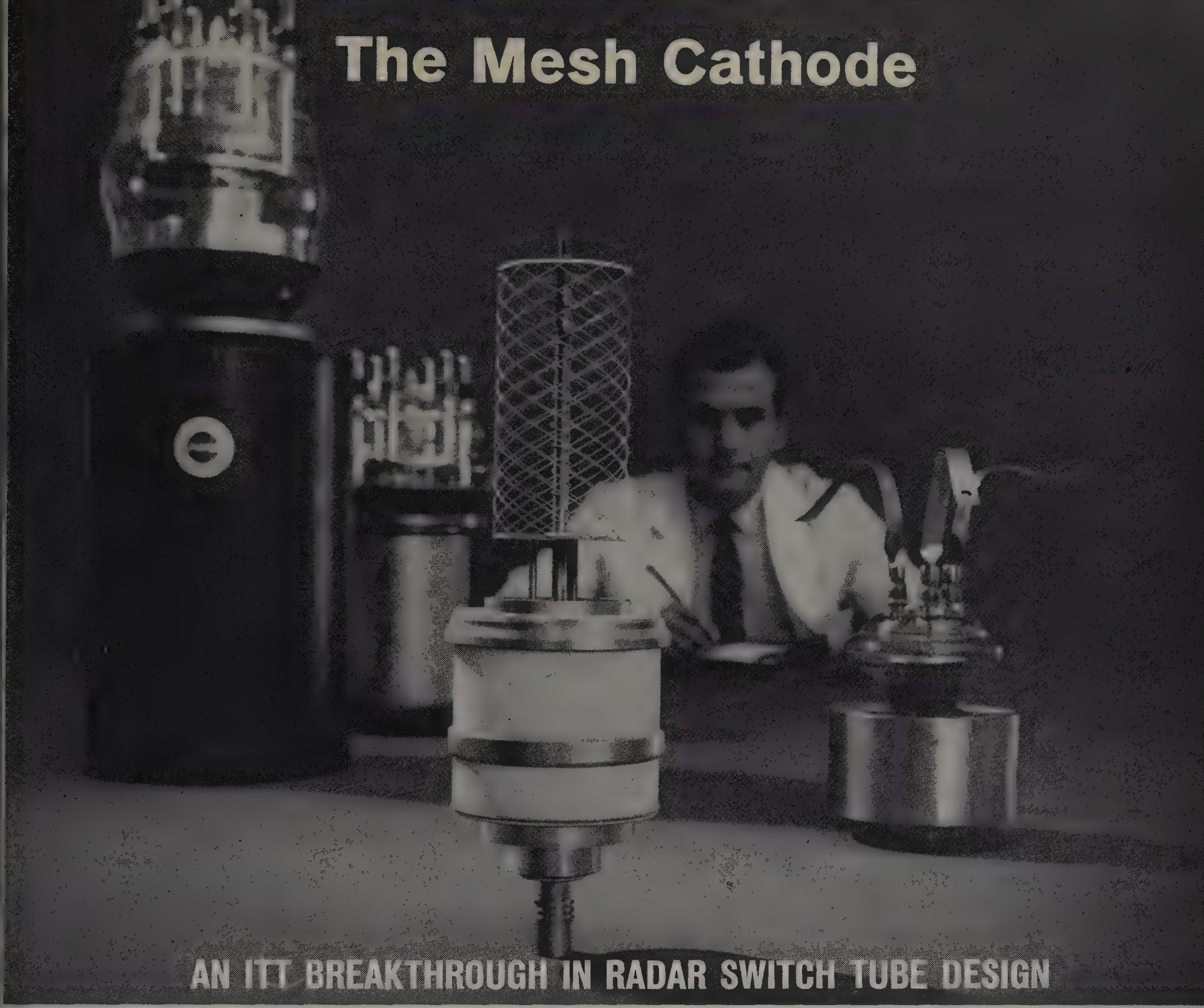
Residual VSWR is less than 1.02 a the slope is less than 0.1 db. The sta dard units are supplied with a bro band probe, but tunable or RF probes a available on request. The line can calibrated in either inches or centimete

Circle Reader Service Card 111

— *m w j* —

(*Continued on page 112*)

The Mesh Cathode



AN ITT BREAKTHROUGH IN RADAR SWITCH TUBE DESIGN

This seemingly delicate web of wire is actually the most rugged and structurally stable construction ever developed for power tube cathodes. Consisting of a fine cylindrical mesh instead of the usual filament configuration, the exclusive ITT mesh cathode is now available in a number of high-performance pulse triodes and power diodes. The triodes are specifically designed for radar switching applications; the diodes are ideally suited for rectifier, clipper and charging service.

Mesh cathode construction, in addition to its mechanical advantages, offers improved emission per watt in comparison with conventional cathodes, as well as quick heating and superior temperature stabilization. The cylindrical design results in an emission pattern that uses more of the available grid surface and thus reduces grid emission problems. This latest ITT power tube "first" is probably the closest existing approximation of a theoretically ideal "physicist's cathode."

Write for information on the complete line of ITT pulsed modulator triodes and power diodes. Application assistance is available for your specific requirements.

MODULATOR TRIODES – PULSED OPERATION

TYPE	PULSE POWER OUTPUT [1] (kw)	D-C PLATE VOLTAGE (kv)	PULSE CURRENT [1] (amperes)	PULSE CURRENT [2] (amperes)
F-7206	2200	18	220	350
F-7328	900	20	100	160
F-7839	7800	65	160	230
D-1037	30000	65	650	1000
F-6920	4100	35	140	200
F-7012	90	18	40	65

[1] At rated filament voltage
[2] At elevated filament voltage

HIGH VACUUM POWER DIODES

TYPE	APPLICATION	PEAK INVERSE VOLTAGE (kv)	PEAK CURRENT (amperes)	AVERAGE CURRENT (amperes)
D-1033	Rectifier	60	36	12
	Shunt or Charging	60	150	–
D-1034	Rectifier	50	45	15
	Shunt or Charging	50	200	–
D-1038	Rectifier	40	18	6
	Shunt or Charging	40	100	–
D-1039	Rectifier	65	21	7
	Shunt or Charging	65	100	–

ITT

ELECTRON TUBE DEPARTMENT ■ COMPONENTS DIVISION
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION, CLIFTON, NEW JERSEY

ITT COMPONENTS DIVISION PRODUCTS: POWER TRIODES AND DIODES • IATRON STORAGE TUBES • HYDROGEN THYRATRONS TRAVELING WAVE TUBES • SELENIUM RECTIFIERS • SILICON DIODES AND RECTIFIERS • TANTALUM CAPACITORS

Circle Reader Service Card 63

NOW...the smallest microwave oscillators we've ever made!

Microwave projects, impossible before, are now possible with these new sub-miniature Trak microwave oscillators. Limited quantities of developmental models now available.

TRAK TYPE 9180 Size: 3/8" long by 3/4" diameter, excluding projections. Frequency: plate pulse, 4.5 KMc to 6 KMc; CW service, 4.0 to 5.5 KMc. Tuning range is limited to approximately 100 megacycles.

TRAK TYPE 9181 Size: 1½" long by 9/16" diameter, excluding projections. Frequency: CW service, 5.0 KMc to 6.0 KMc with tentative tuning range of 400 megacycles.

TRAK MICROWAVE offers a complete line of microwave energy sources including oscillators, amplifiers and harmonic generators. Write for Catalog 61-A.
See our WESCON display — Booth 2117; ISA display — Booth 501.

TRAK Microwave

TRAK MICROWAVE CORPORATION

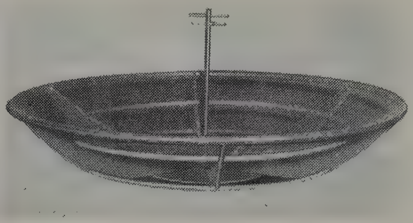
5006 N. Coolidge Avenue
Tampa 3, Florida
PHONE: REdwood 6-6422 or REdwood 6-6407

Specialists In Miniature Microwave Energy Sources

New Products

(*Continued from page 110*)

PARABOLIC ANTENNAS OFFERED BY TACO



Technical Appliance Corp., Sherburne, New York, announces 36 newly catalogued models of both spun and mesh parabolic antennas in sizes from 4-12 feet, for UHF Translator, Studio-Transmitter Link, or government applications.

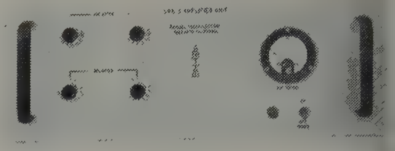
Special features include the ability to mount feed from front or rear and the interchangeability of different feed designs. All feeds are continuously adjustable throughout 360 degrees in spun reflector models — in steps of 90 degrees in mesh models.

TACO, a designer and manufacturer of microwave antenna systems provides all popular frequency bands for industry and the military. Complete "one-stop" service is available through a comprehensive line of mounts, anti-icing equipment and accessories.

Circle Reader Service Card 112

—*mwj*—

ATI INTRODUCES TELEMETRY AMPLIFIER



Applied Technology, Inc., Palo Alt Cal., offers a telemetry amplifier featuring dual inputs with separate calibrate adjustable attenuators. The model VHA-3 finds application as a line amplifie in telemetry and data link installations.

Covering the 215-265 Mc frequenc range, the VHA-3 provides 43 db gain and a saturated power output of 24 dbm An output rf power monitor is provided

Mounting of the VHA-3 is standar rack type with a panel height of seven inches and a chassis depth of 10 inches weight is 21 lbs. Prime power requirements are 109-121 v ac, single phase 60 cps at 0.6 ampere.

Price is $3200 f.o.b., Palo Alto, Cal. and delivery is within 60 days.

Circle Reader Service Card 113

—*mwj*—

(*Continued on page 114*)

For the answers to problems in the design, fabrication, and installation of antenna systems in the fields of scatter communications, missile tracking, space tracking, radar and surveillance, radio astronomy and special antenna products . . .

ASK ASI!

A S I

FOR FULL INFORMATION WRITE: **ANTENNA SYSTEMS INC.**
HINGHAM, MASSACHUSETTS

Circle Reader Service Card 65

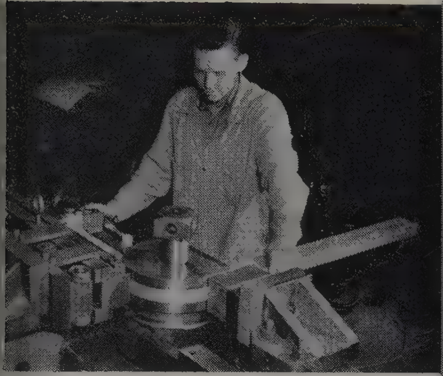
Circle Reader Service Card 64

here's how a four-bend waveguide is processed at specialty automatic

Waveguide, taken from stock . . . is first cut to proper length . . . and then annealed for bending.

Special laminated shims must now be inserted into the waveguide to prevent its collapse during the bending process.

The proper die is then placed in position in the automatic bending machine preparatory to making the first bend.



Here the waveguide is shown still in the bending machine just after the first of the four bends has been made.

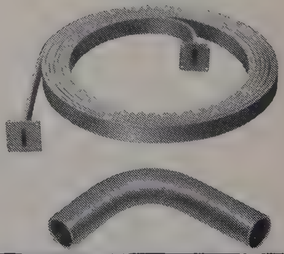
The shims are now removed in preparation for the next step in the bending process.

After each bend the waveguide is sized and the angle is checked to assure that all tolerances are correctly maintained.

Prior to each of its subsequent bends the waveguide must be properly positioned to give accurate register of the next bend (illustration left). The second, third and fourth bends are shown here as each has been processed on the automatic bending machine.

After the final bend has been made, sized and checked, rigid inspection takes place, assuring accuracy of the completed waveguide.

Whatever your needs — bends, twists, offsets, coils, transitions, fabrications, complete assemblies — SPECIALTY AUTOMATIC is ready to precision manfacture to your prints.



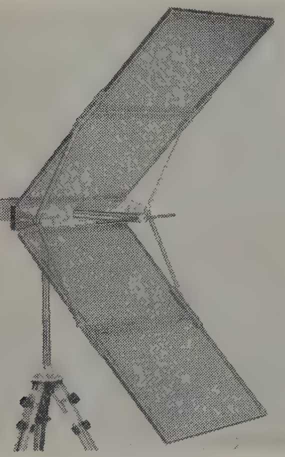
Specialty AUTOMATIC MACHINE CORPORATION

80 Cambridge Street, Burlington, Massachusetts • BRowning 2-0800

New Products

(*Continued from page 112*)

ACCESSORIES AVAILABLE FOR NOISE AND FIELD INTENSITY METER



Accessories to broaden applications of Noise and Field Intensity Meters are now available from Empire Devices, Inc., Amsterdam, N.Y. Although designed specifically for use with Empire Devices Models NF-105 and NF-205, they are similarly useful with other instruments in their frequency range.

Corner Reflector Antenna, Model RA-105, is designed for use over the frequency range 400-1000 Mc, where sensitivity in excess of that obtainable from a dipole is required. The use of a corner reflector is specified by MIL-STD-449. Model RA-105 affords an improvement in gain of at least 10 db over a dipole antenna; a calibrated rule is furnished to facilitate proper setting of dipole length and spacing from the reflector.

Clamp-On Probe, Model CP-105, permits measurement of rf interference in power leads without direct connection to these leads; this avoids breaking of high current leads or disassembly of cable harnesses. Designed for flat response, the unit exhibits unity transfer impedance when used with the NF-105 or NF-205, and avoids completely the use of correction charts or factors.

Also newly available, in three models covering 150 kc - 400 Mc, are Rejection Filters which permit measurement of weak signals in the presence of very strong off-frequency signals. Each filter contains an effective parallel-resonant circuit which, when series connected in the receiver input lead, rejects the interfering signal with negligible effect on the desired signal.

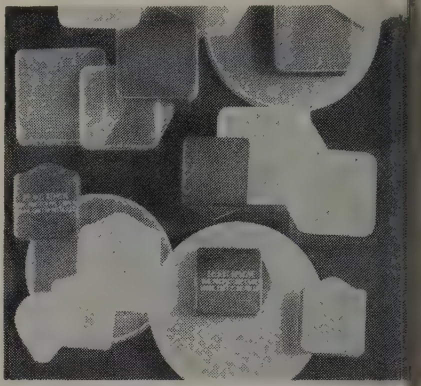
Circle Reader Service Card 114

— *m w j* —

TECHNICAL PLASTICS OFFERS POLYETHYLENE MICROWAVE FLANGE COVERS

Technical Plastics Co., Norwood, Mass., has introduced a series of 35 different low-density polyethylene microwave flange covers, each designed provide effective all-round flange pr tection for interplant, masking and shi ping purposes.

The inherent properties of the pol ethylene provide maximum shock prote tion but do not permit the cover scratch the flange. Strict molding tole ances provide a tight fit that eliminat the need for additional masking tim and material.



Styles are available for flanges use with EIA waveguide designations fro WR28 through WR650. In addition special sizes are stocked or are availab to customer specification and severa standard and metallic colors are offered.

Circle Reader Service Card 115

— *m w j* —

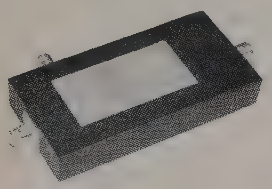
(*Continued on page 116*)

WIDEBAND COAXIAL DIRECTIONAL COUPLERS

For the entire 250-4000 Mc range — at lowest industry prices*

MODEL	COUPLING -NOMINAL	RANGE	PRICE
RDC-3-	10, 20, 30 db	250-500 Mc	$90.00
-4-	"	500-1000 Mc	90.00
-5-	"	1000-2000 Mc	90.00
-6-	"	2000-4000 Mc	90.00

*Delivery from stock after October 15, 1961



Impedance: 50 ohms

Average Coupling: ±0.5 db of nominal

Frequency Sensitivity: ±0.8 db max.

Connectors: Type N (LT, HN, TNC, BNC, C to special order)

Directivity: 20 db minimum

Perpetual, in-the-house Development Programs make "R - D - C" the Microwave Industry's *most versatile* supplier of SPECIAL and STANDARD Coaxial Components:

- ABSORBERS
- ADAPTERS
- ATTENUATORS
- BOLOMETERS
- COUPLERS
- DETECTORS
- FILTERS
- MISMATCHES
- POWER DIVIDERS
- TUNERS
- TERMINATIONS, FIXED
- TERMINATIONS, SLIDING
- SLOTTED LINES
- WAVEMETERS
- SPECIALS

RADAR DESIGN CORPORATION

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Syracuse 11, New York

GLenview 4-4418
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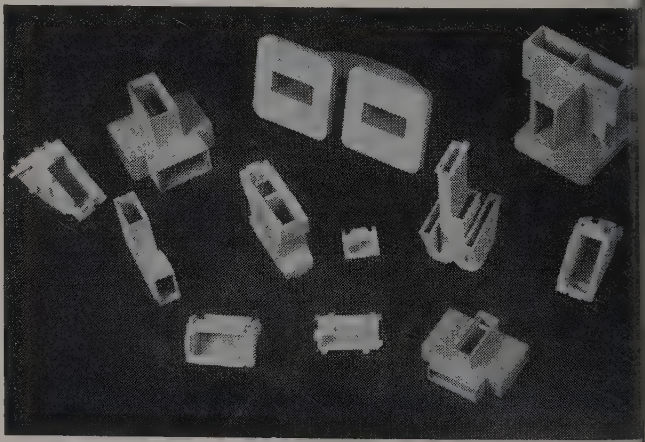
RODÉ

QUALITY INTRICATE WAVEGUIDE CAST TO CLOSE TOLERANCE — FINE FINISH



CASTINGS IN
BRAZEABLE ALUMINUM
BERYLLIUM COPPER

RODÉ, INC.
WOBURN, MASS.
WEll s 3-3580

Circle Reader Service Card 68

expressway for automatic all-weather landings

SPECO The Steel Products Engineering Division of Kelsey-Hayes is developing the radar antenna mounts for **Bell Aerosystem's** All-Weather Automatic Landing System. Designated AN/SPN-10 by the Navy, the system has been selected for use aboard the nuclear-powered aircraft carrier USS Enterprise and other large carriers.

Since 1914, Speco has been a vital force in the nation's aviation and defense programs . . . and since 1949, has provided radar componentry for Titan, Hawk, Nike-Hercules, Nike-Zeus and many other guidance systems. For further information, write Speco Division, Kelsey-Hayes Co., Springfield, Ohio.

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TOWERS

For your micro-wave tower requirements, get the advantages of advanced design, superior workmanship, competent engineering assistance, and complete erection service.

FREE *details gladly sent on request. ROHN Representatives world-wide.*

ROHN *Manufacturing Co.*
P.O. Box 2000
Peoria, Illinois

"Pioneer Manufacturers of Towers of All Kinds"

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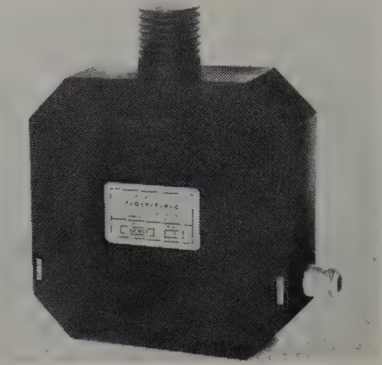
New Products

(*Continued from page 114*)

RANTEC ANNOUNCES Y-JUNCTION CIRCULATOR



Rantec Corp., Calabasas, Cal., announces a UHF L-band three port Y-Junction Circulator, Model CU-900. This circulator operates on the near side of resonance and therefore uses small permanent magnets, resulting in a small size and weight.

Bandwidths of 18 per cent are available with 20 db minimum of isolation, 0.4 db maximum insertion loss and 1.25:1 maximum VSWR. Typical frequency ranges are 1.0 - 1.2 kMc, or .965 - 1.15 kMc over the temperature range —20°C to +71°C. Power handling is 50 watts average.

The units are available in either 120° Y-configuration or a 90° T-configuration, with male or female typ TNC or N connectors. LT connecto are available on special order.

Circle Reader Service Card 116

— *m w j* —

TUBE-CAVITY COMBINATION BEING DESIGNED BY GE

A tube-cavity combination to serve an X-band local oscillator is being d signed by General Electric, Owensbor Ky.

A contract to determine the feasibil of producing such a device has bee awarded to the company's Receivi Tube Department by the U.S. Arm Signal Supply Agency at Ft. Monmout N.J.

Terms of the contract call for deve opment of a tube-cavity combination u ing a metal-ceramic triode as an int gral part of a resonant circuit. It wi be designed to oscillate at 9600 Mc wit a CW output of five milliwatts.

Importance of the integral tube-cavit combination is that a highly trained tech nician is not needed to replace it.

Circle Reader Service Card 117

— *m w j* —

(*Continued on page 118*)

SHARP CUTOFF and HIGH REJECTION

RLC ELECTRONICS INC.

RLC F-30 LOW PASS FILTERS

Pass Band VSWR: 1.3 max.
Pass Band insertion loss: 0.2 db max.
Stop Band Rejection (1.35 to 5.0 fc) 60 db min.
Power: 100 watts
Impedance: 50 ohms
Connectors: N, C, TNC

Model F-30 Standard Units

CUTOFF FREQUENCY (Mcs)	LENGTH (Inches)	CUTOFF FREQUENCY (Mcs)	LENGTH (Inches)
100	12 ¼	2000	6 ½
200	12 ¼	3000	5 ⅞
300	12 ¼	4000	5 ¼
400	12 ¼	6000	4 ¾
600	11 ¼	8000	4 ¾
800	9 ⅛	10000	4 ¼
1000	7 ⅛		

Sharp cutoff and high rejection in the Stop Band assured by multi-section design. High dielectric materials and unique construction provide minimum pass band VSWR and insertion loss and minimum size.

Special filters for other frequencies can be supplied. Write for data.

R L C ELECTRONICS, INC.
805 MAMARONECK AVENUE • MAMARONECK, NEW YORK • OWens 8-7440

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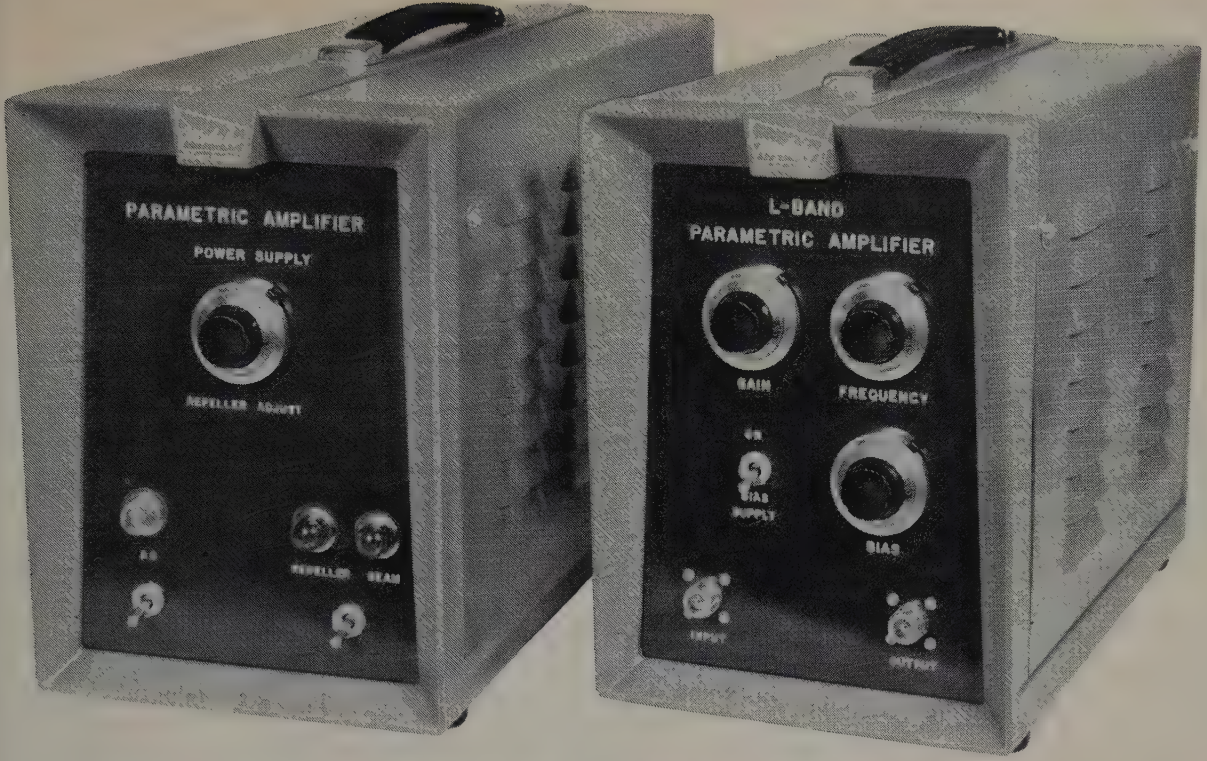
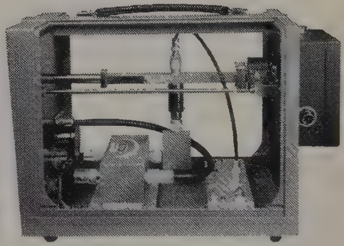


Melabs

PARAMETRIC AMPLIFIERS

with exceptional stability



Shown is Model X-316, a typical **Melabs** high-stability L-band parametric amplifier. The many exclusive features of this **Melabs** amplifier are the result of several years of experience in the design of parametric amplifiers and up-converters for operation at frequencies as high as 35 Gc. **Melabs** is also a major supplier of circulators, an important component in this type of equipment.

FEATURES

Radar Noise Figure (single channel)	2 db	Operating Bandwidth	1150-1350 Mc
Bandwidth	10 Mc	Gain	20 db

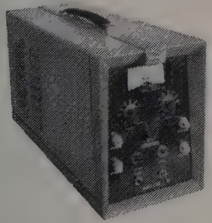
EXCEPTIONAL STABILITY BY—

Highly regulated, well filtered klystron power supply • Temperature controlled klystron environment • Custom designed Melabs' 4-port circulator and iso-attenuator

SIMPLE TUNING—

Single knob frequency control
Single knob gain control
Bias adjust for optimum noise figure

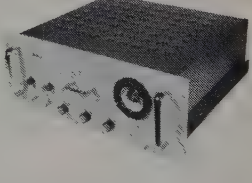
COMPLETE DATA AND SPECIFICATIONS FURNISHED ON REQUEST.



LOW NOISE TWT AMPLIFIERS

The RP Series of TWT amplifiers covering a frequency range of 500 Mc to 18 Gc in six units, is widely used for preamplifiers associated with high sensitivity receiving systems. Units can be packaged for laboratory or military specifications. **Typical Specifications (Model RPL-1):** Frequency range, 1-2 Gc; Gain, 20 db; Noise Figure, 6.0 db. Options include Melabs' RF filters for input and output to minimize possibility of out-of-band interference and a special IAGC circuit which eliminates intermodulation distortion. **Complete details on request.**

UNIVERSAL BEACON TRANSMITTER



The TRO-1 is a medium power transmitter capable of producing 500 to 2000 watt pulses within the 1-6 Gc range. Individual plug-in triode oscillator units are available for most bands. Pulse width is adjustable between 0.7 and 1.0 microseconds. Transmitter is keyed by external synch pulse.

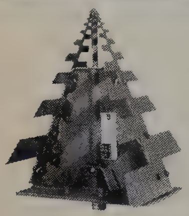
Employment opportunities at Melabs are exceptional for ambitious engineers and physicists; write in confidence.

Melabs

3300 HILLVIEW AVENUE / STANFORD INDUSTRIAL PARK / PALO ALTO, CALIFORNIA
TELEPHONE: DA 6-9500, AREA CODE: 415; TWX: PAL AL 138

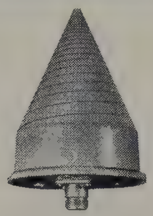
Dept. A-4

FREQUENCY INDEPENDENT ANTENNAS



Model No. APN101A

LOG PERIODIC
LINEAR
POLARIZATION



Model No. ALN108A

CONICAL HELIX
CIRCULAR
POLARIZATION

MODEL NO.	FREQUENCY	MODEL NO.
APN105A	0.05-3.0 Gc	ALN112A
APN106A	0.3 -3.0 Gc	ALN119A
APN101A	1.0-11.0 Gc	ALN108A

The above AEL antennas represent an extensive line of both log periodic and patented conical helix antennas . . . all designed to meet today's dynamic requirements of electronic countermeasures, telemetering and communications systems.

High Gain, broadband performance can be obtained by employing the Conical Helix and Log Periodic feeds with parabolic reflectors. The fundamental limitation to gain-bandwidth of the parabolic configuration is defocussing caused by the phase center movement of the feed. In spite of this limitation, however, 15:1 bandwidths have been achieved with gains in the order of 15 to 30 db. Conical Helix or Log Periodic fed parabolic reflector antenna systems will be quoted on request.

Small volume—Light weight—Rugged Construction—Built for military usage

Investigate the opportunities at AEL for creative engineers

AEL®

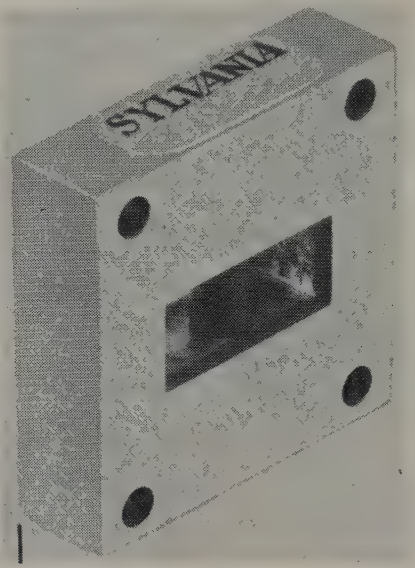
AMER. ELECT. LABS., INC.
Richardson Rd., Colmar, Pa. • Van Dyke 2-0131
In Canada contact: Conway Electronic Enterprises Regd. Toronto, Canada

Circle Reader Service Card 73

New Products

(*Continued from page 116*)

SYLVANIA ANNOUNCES MINIATURE X-BAND ISOLATOR



An X-band ferrite isolator, less than 1/2 inch in over-all length and weighing less than 1.5 ounces, has been made available by Sylvania Electric Products Inc., Mountain View, Cal.

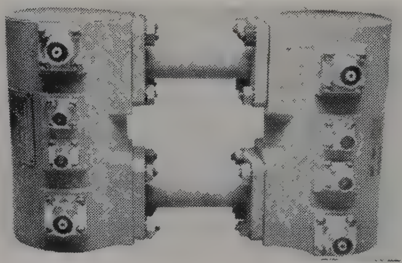
R. A. Stonesifer, product sales manager of Sylvania's Microwave Device Division, said that the unit, designated type FD-5239, provides high electrical performance in such applications as parametric amplifiers, masers, and missiles, where minimum size and weight are essential.

Typical performance characteristics of the FD-5239 are 15 db minimum isolation, 0.5 db maximum insertion loss, and 1.20 maximum VSWR. The isolator operates over a frequency range ± 50 Mc centered at 9.18 Gc. Other frequency ranges of comparable bandwidth in X-band can also be furnished. The body of the device mates with UG-39/U waveguide flanges.

Circle Reader Service Card 118

—*mwj*—

HIGH POWER DUPLEXER ANNOUNCED



Tucor announces a new balanced TR-type duplexer having a 10 kw peak power capability at frequencies from 98 to 160 megacycles.

Designated T47V7, the device is intended for use in data links, communications, electronics and countermeasure applications. The average power rati is 200 watts.

Other specifications include a high an low level insertion loss of 0.5 db, isol tion of 40 db and recovery time of 10 microseconds.

Circle Reader Service Card 119

—*mwj*—

G T & E ANNOUNCES SOLID-STAT TRANSMITTER FOR SATELLITE COMMUNICATIONS

A solid-state microwave transmitt for space communications — occupyi less than the space of a cigarette cart — has been announced by General Tel phone & Electronics Corp., New York N.Y.

Developed for the Air Force, the com pact unit is the first solid-state transmi ter designed to operate with approximate ly two watts of output power within th S-band (1700 to 2300 megacycles).

The transmitter could be combine with a solid-state ultra-reliable radi receiver developed earlier by GT&E t form a complete space communication system. The system would be used fo space probes, or would be a major ele ment in a satellite communications sys tem used to transmit telephone conver sations, business data, or television pro

(*Continued on page 120*)

Delay Lines
fabricated of
PHELPS DODGE
STYROFLEX® SPIRAFIL®
FOAMFLEX® COAXIAL CABLE

A-T can supply Delay Lines fabricated of any Phelps Dodge coaxial cable from 3/8" diameter through 1 5/8" diameter in compact packages to suit your needs. Here is accuracy within ±.02 nanoseconds . . . broader band operation . . . lower attenuation and greater stability.

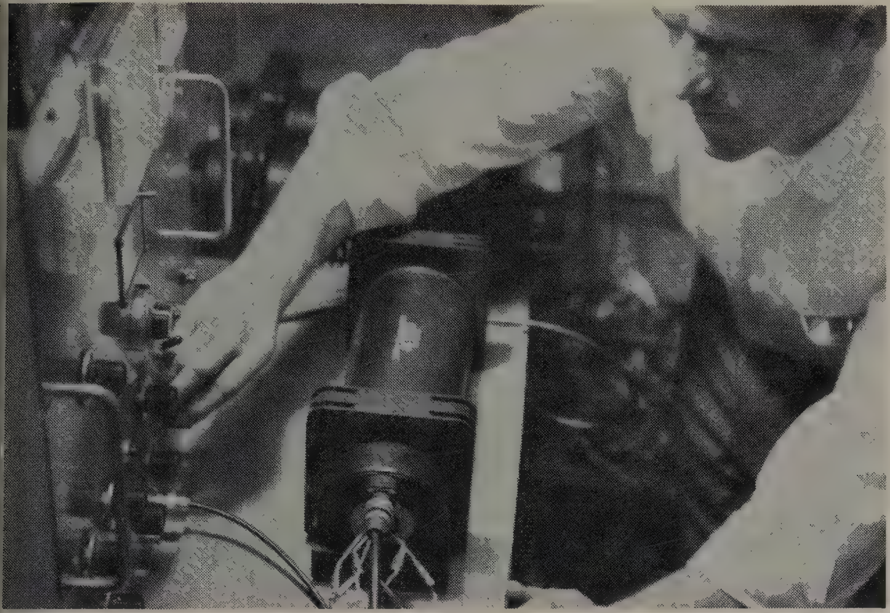
Write for
free catalog

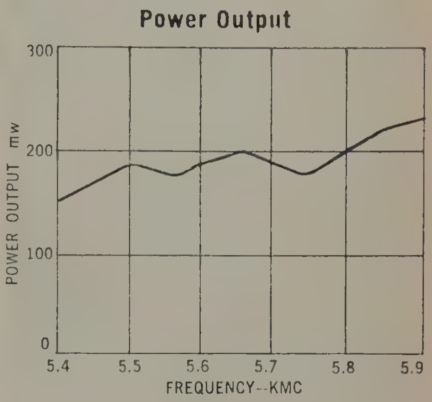
A-T ELECTRONICS, INC.
10 Lawrence Street, New Haven 8, Conn.

FABRICATORS—DISTRIBUTORS
OF PHELPS DODGE
COAXIAL CABLE
See pages 44, 45

Circle Reader Service Card 61

PERFORMANCE CHARACTERISTICS OF TUCOR BACKWARD WAVE OSCILLATORS



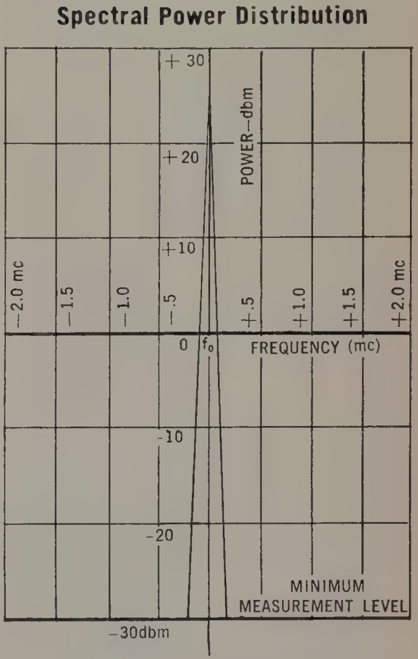


Power Output

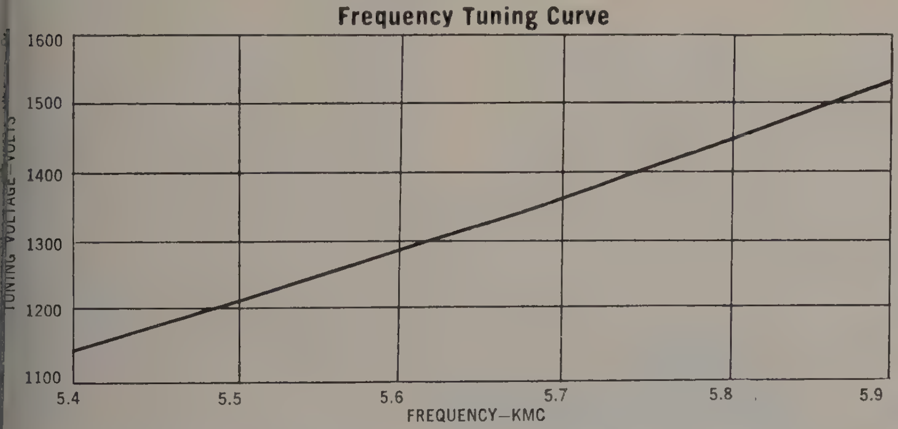
A voltage-tunable signal of exceptional quality is provided by Tucor backward wave oscillators. The spectral purity and stability indicated in the following graphs are maintained by these units under conditions of shock, vibration, temperature and humidity as required for military radar use.

The principle of construction followed is of a hollow-beam gun design in a solenoid-focussed tube which is completely encapsulated within an integral heat sink. A high degree of processing assures low resonance and low noise output at all frequencies.

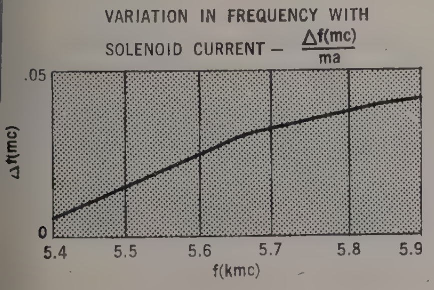
The characteristics listed are for a typical BWO—the Tucor T15C1C, having a frequency range of 5.4 to 5.9 Kmc. Other production units are all detailed in Bulletin B-1.



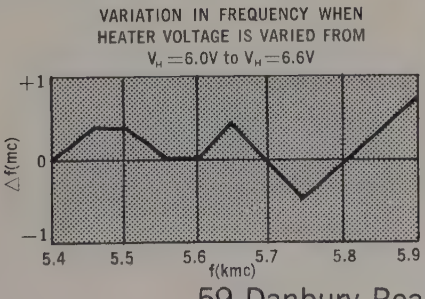
Spectral Power Distribution



Frequency Tuning Curve



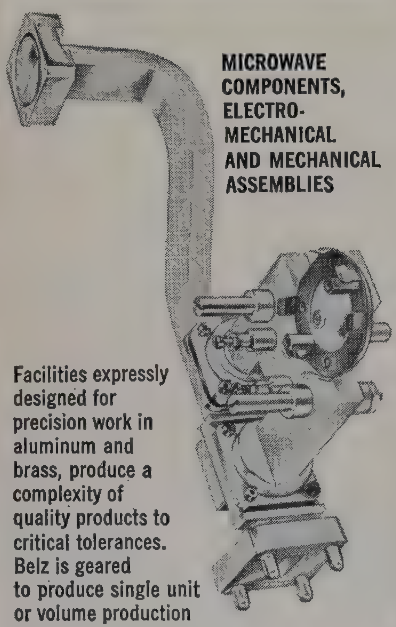
VARIATION IN FREQUENCY WITH SOLENOID CURRENT — $\frac{\Delta f(mc)}{ma}$



VARIATION IN FREQUENCY WHEN HEATER VOLTAGE IS VARIED FROM $V_H = 6.0V$ to $V_H = 6.6V$

TUCOR
INC.

59 Danbury Road (Route 7), Wilton, Connecticut



B + 18 PLUS

B + 18 PLUS = more than 18 years of engineering experience and production know-how in manufacturing advanced, reliable microwave components and assemblies.

Belz Industries' ability to meet critical requirements of military and industrial electronics firms has been consistently proven for almost two decades.

At Belz, skilled personnel, using advanced mechanical and electrical testing equipment... assures strict adherence to your specifications.

Facilities expressly designed for precision work in aluminum and brass, produce a complexity of quality products to critical tolerances. Belz is geared to produce single unit or volume production to the same critical standards.

Inquiries concerning development and/or manufacturing of microwave assemblies and system components are welcome. For descriptive brochure, or quotation on specific production problems, write, wire or call.

BELZ INDUSTRIES
a division of EL-TRONICS, INC.
89 UNION STREET • MINEOLA, N.Y.
Pioneer 2-1010

Circle Reader Service Card 75

(*Continued from page 118*)

grams on a world-wide basis, utilizing satellites 22,300 miles above the earth as relay stations.

The transmitter and receiver were developed by the Amherst (N.Y.) Laboratories of Sylvania Electronic Systems, a major division of the company. Sylvania Electronic Systems has over-all responsibility for systems management of GT&E's major government projects.

Circle Reader Service Card 120

— *m w j* —

RCA DEVELOPS INTEGRAL-CAVITY PENCIL-TUBE OSCILLATORS

Six new pencil-tube oscillators have been developed by the Radio Corporation of America, New York, N.Y.

The developmental, lightweight, integral-cavity units are available in the frequency range from 900 to 3400 Mc. for both pulse and CW applications.

The small, inexpensive units can be made rugged enough to withstand the severe environmental conditions found in airborne equipment and have excellent frequency stability over a wide range of temperatures.

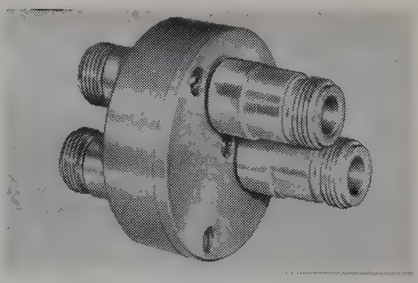
The light weight (two ounces) and low power consumption enable the pulsed-type oscillators to be used in the design of new lightweight equipment for air traffic transponders, radar beacons, drones, and telemetering devices. These oscillators can be either cathode or plate-pulsed. They are also suitable for use as parametric-amplifier pumps, as local oscillators, and as self-pulsed oscillators.

Circle Reader Service Card 121

— *m w j* —

MICROLAB INTRODUCES SERIES OF COAXIAL HYBRID RINGS

Microlab, Livingston, N.J., announces a series of coaxial hybrid rings. Called the CJ type, they consist of a coaxial line in the shape of a circle of 1 1/2 wavelengths circumference with four branch arms.



The CJ hybrids may be employed as balanced mixers, passive diplexers, power combiners, power dividers, variable phase shifters, balanced diplexers and as variable attenuators.

The characteristic impedance of th coaxial ring is chosen such that any o the three arms will present an inpu impedance of 50 ohms when the othe three arms are terminated in 50 ohms.

The hybrids are designed to operat over a 15 per cent bandwidth and a available in frequency ranges from 95 6000 Mc. They have a maximum inser- tion loss of 0.2 db and an isolation o better than 25 db.

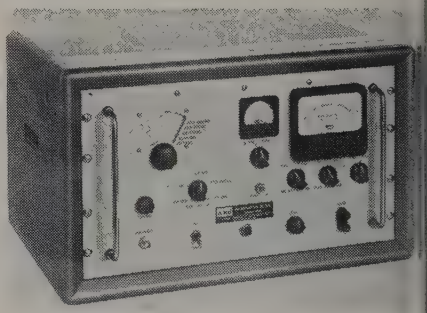
Priced at $120 to $150, dependin upon frequency range and connecto type, they are available for immediat delivery from stock.

Circle Reader Service Card 122

— *m w j* —

ADVANCED MEASUREMENT DEVELOPS FM DEVIATION METER

An FM deviation meter developed by Advanced Measurement Instruments, Inc. Somerville, Mass., measures peak posi- tive or negative deviations of composit wave shapes with better than two per cent accuracy.



Designated as the AMI Model 400 FM Deviation Meter, the instrument enables carrier frequency range to be read direct- ly within ±0.5 per cent from 20 to 100 Mc., and indicates peak deviation directly to 1000 kc.

Applications of the Model 400 extend from monitoring FM transmitters to measuring telemetering signals by producing a demodulated output that can be analyzed for distortion, hum, and spurious responses.

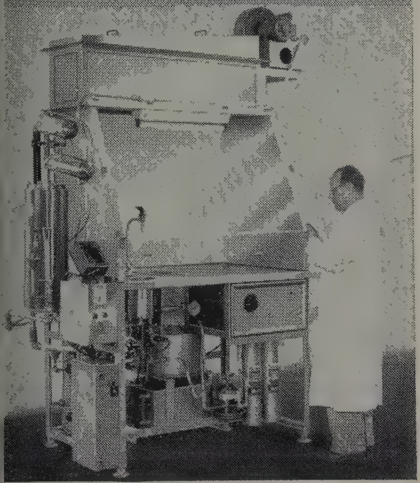
The AMI Model 400 FM Deviation Meter is essentially a broadband FM receiver with an ultra-linear discriminator and accurate readout. Deviation is indicated by a linear voltmeter with FSD accuracy within two per cent. Five peak deviation ranges are provided: ± 10, ± 30, ± 100, ± 300, and + 1000 kc. Resolution in the 10 kc. range is 100 cps. Demodulation distortion is less than 0.2 per cent, assuring high-accuracy deviation measurements. Carrier shift is indicated directly to ± 250 kc., with accuracy of five per cent.

Circle Reader Service Card 123

— *m w j* —

(*Continued on page 121*)

NEW COMPLETE CLEANING STATION



FOR WASHING ELECTRONICS COMPONENTS

Here's your one-stop, one-location cleaning station for final washing and rinsing of transistors, diodes, crystals and other components. Eliminates need to maintain large "clean" areas which add to operating costs. Reduces transporting and handling while cleaning and rinsing costs are sharply reduced because the unit is largely regenerative. Illustrated unit can be modified to meet a wide variety of washing and rinsing requirements.

INEXPENSIVE TO OPERATE

Both ultra pure hot water and Freon rinsing systems are designed for continuous recirculation and repurification to keep operating costs low. A three gallon per hour Still supplies make-up water. Freshly distilled Freon is continuously fed into the Freon rinse chamber. Contaminated Freon returns by gravity to a Freon Recovery Still.

NEW BULLETIN

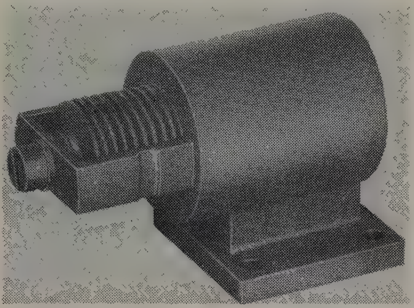
New Bulletin #166 describes the complete line of Barnstead Transistor Washers. Cut reject rate, provide more efficient final rinse, and save on pure water and heat. Write for your copy today.

Barnstead®
STILL AND STERILIZER CO.
48 Lanesville Terrace, Boston 31, Mass.
Circle Reader Service Card 76

(*Continued from page 120*)

FREQUENCY STANDARDS' REFERENCE CAVITY PROVIDES ±.005 PER CENT ACCURACY

An accuracy of ±.005 per cent is provided in a reaction type reference cavity produced by Frequency Standards, Asbury Park, N.J.



Designed for use in microwave relay links, the cavity is adjustable within a frequency range of 10.7-11.7 Gc and exhibits a maximum resonant frequency shift of 1.0 Mc over a temperature range of 0°F to 140°F. Invar construction provides an accuracy of ±.005 per cent when once set to resonance.

The cavity is equipped with a flange which mates mechanically and electrically with other type WR 90 waveguide components. A bellows drive coupling with screw type tuning mechanism is furnished. The entire unit is hermetically sealed.

Dimensions are 2 1/2 x 1 1/2 x 1 1/4 inches; weight, six ounces; price, $100 to $150 each depending on quantity, and delivery is 45 to 60 days.

Circle Reader Service Card 124

—*mwj*—

QUANTATRON ANNOUNCES DON-LAN MICROWAVE COAXIAL SHUTTER

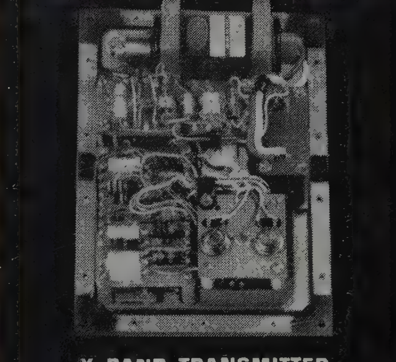
Quantatron, Inc., Santa Monica, Cal., announces that its subsidiary Don-Lan Electronics Inc. is producing in quantity their model S-70 Coaxial RF Shutter. The shutter is an electrically-operated device designed to protect crystals, receivers and other power-sensitive devices and equipment from rf overloads.

With the actuator energized, the shutter, when inserted in an rf transmission line, passes power with negligible attenuation. Designed for fail-safe operation, the shutter provides 40 db isolation (to four Gc) upon failure or removal of actuator power. Operating time is six milliseconds.

S-70 shutters are well-suited for critical airborne, missile and shipboard applications. They are small (2.9 x 0.9 x 1.5 inches), light (1.5 ounces) and rugged. Normally used over an ambient range of —65°F to 160°F, higher temperature versions are available. They are

(*Continued on page 122*)

ACF MICROWAVE EQUIPMENT



X-BAND TRANSMITTER
TYPE NO. 501

COMPACT DESIGN WITH NO PERFORMANCE PENALTIES. SYSTEM-TESTED FOR OPERATIONAL SPACE VEHICLES. ENGINEERED TO MEET COMPLETE MILITARY MISSILE SPECIFICATIONS.

Frequency Range: 8900 mc to 9400 mc
Wave Guide Power Output: 1,000 Watts, peak
Duty Cycle: 0.002 (maximum)
Pulse Width: 0.45 u seconds ± 0.1 u seconds
Minimum Pulse Spacing: 90 u seconds
Modulation: Pulse
Modulator: Solid State
Input Voltage: 24-30 V DC @ 1 amp.
6 V DC @ 0.45 amp.

May be operated as a free-running pulse transmitter or used with a commutator type telemetry unit capable of providing PPM triggering signals at rates up to 900 bits/sec.

Standard designs modified to meet specific requirements. Complete manufacturing and engineering resources supported by local field service. Full line of components for L, S, C or X-Band Frequencies.

ACF Beacons have qualified for more major satellite and missile programs than any other beacon.

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ACF ELECTRONICS
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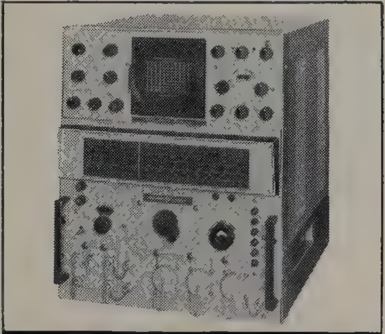
TELEPHONE: COLFAX 1-4100

Circle Reader Service Card 77

more usable sensitivity
10 mc to
44,000 mc
IN ONE TUNING HEAD



PANORAMIC'S
SPA-4a
SPECTRUM
ANALYZER

Band	RF SENSITIVITY*
1. 10 - 420 MC	—100 to —110 dbm
2. 350 - 1000 MC	— 95 to —105 dbm
3. 910 - 2200 MC	—100 to —110 dbm
4. 1980 - 4500 MC	— 90 to —100 dbm
5. 4.5 - 10.88 KMC	— 90 to —100 dbm
6. 10.88 - 18.0 KMC	— 85 to —100 dbm
7. 18.0 - 26.4 KMC	— 70 to — 90 dbm
8. 26.4 - 44.0 KMC	— 60 to — 85 dbm

*Measured when signal and noise equal 2X noise.

Using one tuning head which contains one triode and two Klystron oscillators, Model SPA-4a offers more exclusive advantages for applications demanding extreme sensitivity, stability, versatility, accuracy.

• Exceptionally low distortion • Highly resolved & calibrated analysis • Three precisely calibrated amplitude scales — 40 db log, 20 db linear, 10 db power. • Two independent frequency dispersion ranges — continuously adjustable —0—70 mc and 0—5 mc. Negligible internal frequency modulation permits narrow band analysis of FM problems. • Variable I.F. bandwidth from 1 kc to 80 kc. • Push-button frequency selector. • Synchroscope output with 40 db grain. • Accurate measurement of small frequency differences. A self-contained marker oscillator, modulated by a calibrated external generator, provides accurate differential marker pips as close as 10 kc.

Tremendous flexibility and many unique advances of Panoramic's compact SPA-4a make it unsurpassed for visually analyzing FM, AM and pulsed signal systems; instabilities of oscillators; noise spectra; detection of parasitics; studies of harmonic outputs; radar systems and other signal sources.

Write, wire or phone today for detailed SPA-4a bulletin.

the pioneer is the leader

WE CATALOG IN eem electronic engineers master

Panoramic electronics, inc.

Sec. 2900

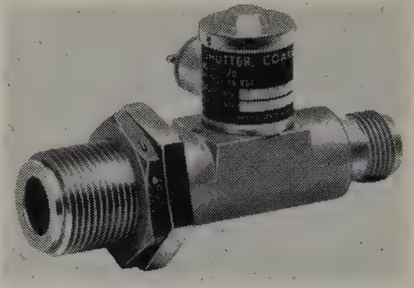
See Us At E.I.M.E.

See Us At NEC — Booth 401

Formerly Panoramic Radio Products Inc.
556 So. Fulton Ave., Mount Vernon, N.Y.
OWens 9-4600 • TWX: MT-V-NY-5229
Cable: Panoramic, Mt. Vernon, N.Y. State

(*Continued from page 121*)

designed to meet the applicable requirements of MIL-E-5272.

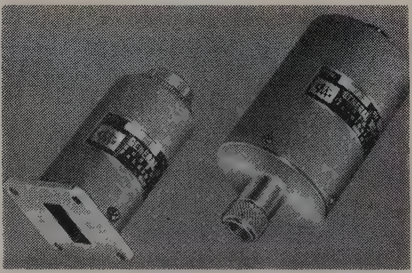


Don-Lan S-70 series shutters can be tailored to meet specific microwave system requirements. All standard coaxial connectors or combinations of these can be furnished. A stripline version has been designed for an advanced missile. Actuators operating from 115 vac (60 or 400 cps) or six to 115 vdc can be provided.

Circle Reader Service Card 125

— m w j —

GENERAL MICROWAVE ANNOUNCES TEMPERATURE-COMPENSATED THERMISTOR MOUNTS



General Microwave Corp., Farmingdale, N.Y., announces the availability of its model 402 Series of Temperature-Compensated Thermistor Mounts covering the frequency range from 0.01 — 18.0 Gc.

The mounts are designed for measurement of a wide range of CW or modulated powers in conjunction with GMC model 450 Precision Microwave Power Meter, which features a direct-reading accuracy of 0.5 per cent of full scale. Extremely low drift is achieved for this combination by the use of a dual thermistor-bridge system. The two thermistors required are both housed in the model 402 in close physical proximity to ensure similar thermal environment and good tracking characteristics. By means of this arrangement, thermal drift of the combination is less than two microwatts per-degree centrigrade.

The direct-reading power measurement range of the model 402 Series in conjunction with model 450 Power Meter is 0.5 microwatts to 10 milliwatts.

Circle Reader Service Card 126

— m w j —

◄ **Circle Reader Service Card 78**

HIGH-SPEED WIDE BAND COAX SWITCH PRODUCED BY SANDE

A high-speed, wide band coax swit is now in production by Sanders Ass ciates, Inc., Nashua, N.H. In a sma low-cost package it provides SPDT a tion over the frequency range of 0.1 M to 400 Mc with switching speed of nanoseconds. At 200 Mc the open circ attenuation is greater than 55 db ar the insertion loss less than one db.

The switch, a solid state device wi high reliability, measures 3/4 inch 1 3/4 inches x 3 3/4 inches and weig less than 2 1/2 ounces. Offering a hig order of switching performance prev ously available only with bulky electr magnetic coax or ferrite devices, th unit is specially recommended for sy tem applications.

Some typical applications in system work are: in multiplexing, feeding time-shared antenna or feeding one r ceiver from many time-shared source in signal suppression of unwanted si nals such as T-R devices in a receive in pulse modulation, as a broadban pulse modulator with a high frequen modulation rate of 500 kc or highe and in steering, to direct VHF signa into different channels for different sy tem modes of operation.

Solid state design of the new swit assures high reliability under tough e vironmental conditions. Temperatu range is —65°C to +70°C. It pass shock qualification tests of 30g at milliseconds, all axes, and vibratio tests of 20g at 5-20,000 cps, all axes.

Circle Reader Service Card 127

— m w j —

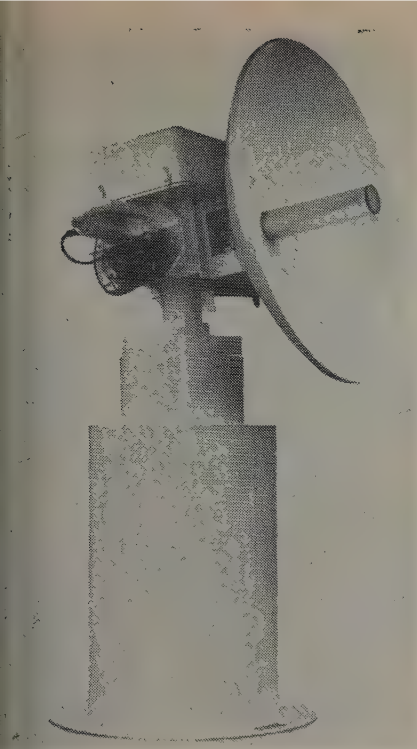
LOW WEIGHT ANTENNA MOUN PRODUCED BY TEMEC

A low weight servo controlled pede tal for shipboard and ground based ap plications is available from Temec, Inc Van Nuys, Cal. Weighing less than 10 lbs, antenna mount model 28 is design for use in telemetry reception and th tracking of aircraft missiles and sate lites.

Features include gyro stabilization fo shipboard use, a complete solid state a servo system, and automatic beam cros over switching from 3 db — 9 db. Cu rent production model employs a fiv foot reflector for use in the 5 kMc rang but other reflectors and frequencies a available on order. The current syste has slew rates of 36°/sec and acceler tions of 130°/sec/sec.

Remote stowing is accomplished electromechanical brakes located on th pedestal. One-quarter hp servo moto are used for this purpose but current d signs permit one hp motor to be em ployed.

An azimuth rotation of 710°, wit hydraulic stops, is currently availabl but slip rings may be provided to f



cilitate continuous rotation. Dynamic braking is provided automatically to protect the mechanical structure from shock loading should a mechanical limit be reached.

Circle Reader Service Card 128

— mwj —

RANGE OF EMPIRE DEVICES INTENSITY METER EXTENDED DOWN TO 14 KC

Now available from Empire Devices, Inc., Amsterdam, N.Y., is a tuning unit which extends the range of the widely-accepted Noise and Field Intensity Meter, Model NF-105, downward to 14 kc, thus providing continuous coverage from 15 kc - 1000 Mc.

Designated Model T-X/NF-105, the tuning unit is compatible with all existing NF-105 basic units and fills the need for accurate and convenient instrumentation at these lower frequencies.

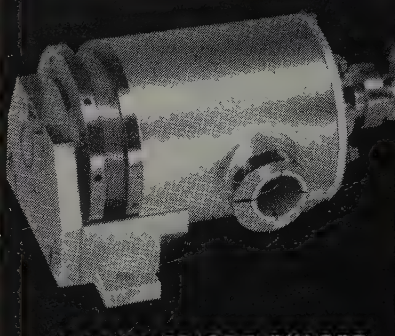
Tuning from 14 kc - 150 kc is provided in three ranges: 14-25 kc, 25-62 kc, and 62-150 kc; nominal bandwidth is one kc and full-scale sensitivity is 0.1 microvolt.

Available as accessory items are a 36 inch diameter loop antenna, a 41 inch vertical antenna, a line probe and a carrying case. Also available is a vertical antenna which can be remotely operated up to 30 feet away from the instrument. All pickup devices employ matching couplers to afford efficient energy transfer into the 50-ohm input impedance of the tuning unit.

Circle Reader Service Card 129

— mwj —

(*Continued on page 132*)



ACF MICROWAVE EQUIPMENT

C-BAND TRIODE PULSED OSCILLATOR MODEL NO. 338

SPECIFICALLY DESIGNED FOR TRANSMITTER SERVICE IN MISSILE AND DRONE TYPE RADAR BEACONS.

Maximum miniaturization with no performance penalties. System-tested for operational space vehicles. Engineered to meet complete military missile specifications.

Frequency Range: 5400 to 5900 mc

Power Output: 1.5 kw min. (200 mc tuning range)
1.0 kw min. (500 mc tuning range)

Stability: ± 3 mc over the most stringent air-borne environmental conditions.

Pulling Factor: Less than ± 2.5 mc for 1.5 VSWR, all phases.

Pushing Factor: Less than 5 kc/peak ma.

Load Variation: Can withstand VSRW's of 6:1 at any arbitrary phase without impairing life expectancy.

Standard designs modified to meet specific requirements. Complete manufacturing and engineering resources supported by local field service. Full line of components for L, S, C or X-Band Frequencies.

ACF Beacons have qualified for more major satellite and missile programs than any other beacon.

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NEW moderately priced high-precision SLOTTED LINES

- Rated residual VSWR under 1.010; rated error in detected signal under 1.005.

An AMCI Type 2181 Slotted Line with interchangeable precision tapered-reducers provides for accurate measurements in several transmission line sizes from Type BNC to 1⅝" or larger. An untuned rf probe is supplied as part of the slotted line. Several tunable detector probes are available as optional accessories.

Type	Frequency range	Slot length	Price*
2181-2	300 to 4000 mc	20 inches	$700
2181-3	200 to 4000 mc	30 inches	$750
2181-4	150 to 4000 mc	40 inches	$800
2181-6	100 to 4000 mc	60 inches	$925

*including an input adapter to Type N and an untuned rf probe but excluding output tapered reducers and tunable probes. Prices are F.O.B. Boston, Mass., and are subject to change without notice.

Write for complete information on AMCI Slotted Lines.

ANTENNA SYSTEMS – COMPONENTS – AIR NAVIGATION AIDS – INSTRUMENTS
AMCI ALFORD Manufacturing Company
249 ATLANTIC AVE., BOSTON, MASS.

Circle Reader Service Card 79

Complete data on over 200 microwave components

MCS/PRECISION MICROWAVE COMPONENTS
M MICROWAVE
C COMPONENTS &
S SYSTEMS CORPORATION

- all standard items, covering the range from 1.70 to 40.0 GC

Here are electrical and mechanical specs. on the MCS line of precision microwave equipment. All are components of the highest quality — guaranteed in workmanship and performance. All are calibrated on instruments traceable to the National Bureau of Standards.

Custom designs at production prices — these components were designed for specific applications — now they're standards. It could be that many will meet your special requirements with only slight modifications—saving both engineering and tooling.

Typical products covered include ferrite devices • variable and step attenuators • slotted lines • precision low-power terminations • directional couplers • standard gain horns • detector mounts.

MICROWAVE
COMPONENTS &
SYSTEMS CORPORATION • *1001 S. Mountain Ave., Monrovia, Calif.* • *ELliott 7-3285*

Write for catalog #861

Circle Reader Service Card 148

WESGO—*Quality leader in vacuum tube ceramics and brazing alloys!*

High alumina ceramics for vacuum tube envelopes, inte- nal spacers, rf windows, heat sinks, high-voltage insulato ...*your* specific electronic application.

Ultra pure low vapor pressure brazing alloys—a comple range of melting points and wetting characteristics for ar vacuum requirement; wire, ribbon, sheet, powder, preforms

AND THE NEW WESGO FLEXIBRAZ

...a money-saving new form for brazing alloys. Obviates th waste in stamping, gives you totally new versatility, benc to the form you need. Valuable for R&D work, introduce new production-line economies.

"VX" Super Refractory, Wesgo ceramics with uniquely hig resistance to thermal shock. Ideally suited for use in furnac brazing, available in boats, slabs, special brazing fixtures

devoted to the manufacture of products of unparallele quality... to meet the exacting requirements of the vac uum tube industry!

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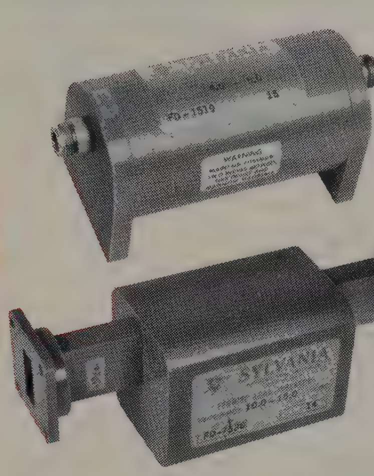
525 Harbor Boulevard • Belmont, California • LYtell 3-3121

Circle Reader Service Card 81

MICROWAVE DEVICE NEWS from SYLVANIA

AVAILABLE IN QUANTITY!



BROADBAND FERRITE ISOLATORS

COAXIAL DEVICES / WAVEGUIDE DEVICES

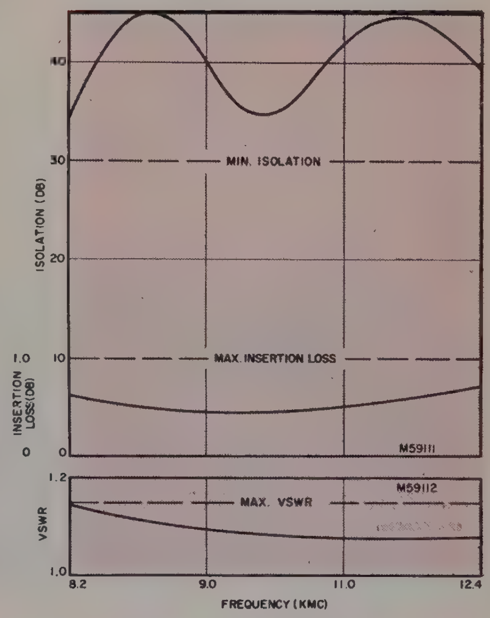
—from 1-11 GC / *—from 3.95-26 GC*

Sylvania offers a comprehensive line of coaxial and waveguide isolators—12 types, in all—featuring extraordinary isolation to insertion loss ratios as high as 30 to 1. Designed for wideband applications in such end-products as ECM and laboratory test equipment, they're extremely well suited for the reduction of VSWR and the elimination of anomalies caused by long line effects in oscillator outputs.

Your Sylvania Sales Engineer will be pleased to tell you more about the full line of *competitively priced* broadband coaxial and waveguide isolators. Ask him. For technical data, write Electronic Tubes Division, Sylvania Electric Products Inc., 1100 Main St., Buffalo 9, N. Y.

BROADBAND COAXIAL ISOLATORS Frequency	Types	Isolation (Min.) (db)	Insertion Loss (Max.) (db)	VSWR
1.0-2.0	FD-1537	10	1.2	1.2
2.0-4.0	FD-151P	15	1.0	1.2
4.0-8.0	FD-1519	10	1.0	1.25
8.0-11.0	FD-1522W	30	1.0	1.4
BROADBAND WAVEGUIDE ISOLATORS				
3.95-5.85	FD-492	18	1.0	1.15
5.85-8.2	FD-502	20	1.0	1.15
7.05-10.0	FD-512	24	1.0	1.2
8.2-12.4	FD-522	30	1.0	1.15
10.0-15.0	FD-7530	30	1.0	1.15
12.4-18.0	FD-911	24	1.0	1.15
18.0-26.0	FD-531A	24	1.0	1.15
18.0-26.0	FD-531AF1	24	1.0	1.15

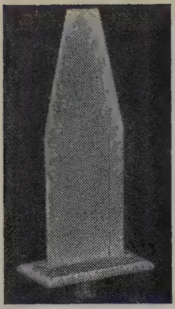
Typical performance characteristics of FD-522



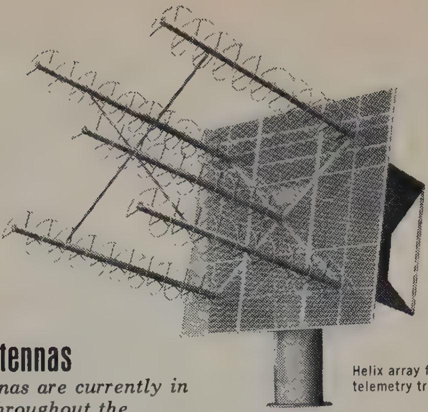
SYLVANIA

SUBSIDIARY OF
GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM



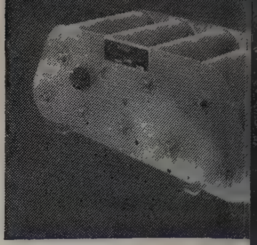
Airborne antennas
ommunication, beacons
nd radar augmentation



Helix array for
telemetry tracking systems

Antennas

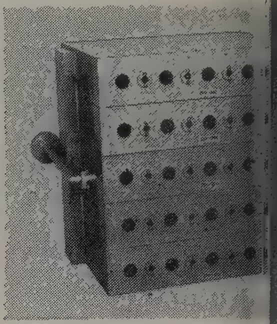
Rantec tracking antennas are currently in operation at missile ranges throughout the free world. In addition, Rantec's airborne antennas are in quantity production for major missile and airframe programs.



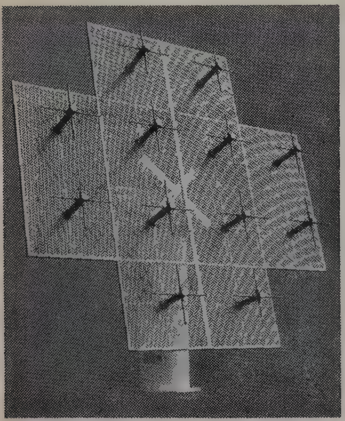
3-channel, high isolation,
low insertion loss multiplexer

Telemetry Antenna Multipl

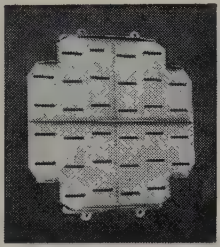
Rantec multiplexers are used on a larg
number of missile and space programs, in
Mercury, Titan, Polaris, Discoverer
Midas, Nike Zeus, Nike H
Subroc, Samos, X-17, Centaur,



5-channel, high isolation,
low insertion loss multiplexer – 225-2



Dipole array for
telemetry tracking systems



Two-dimensional "flat plate"
slot array for missile tracking and
guidance – monopulse or electronically
conical scan applications

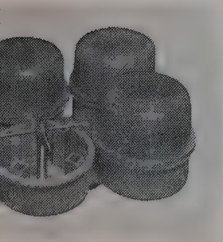
rantechnology

Over the years, a company normally becomes "pegged" into one or two specific categories of interest. Rantec has variously been described as "those people who make antennas" or "they're in ferrites." We would like to take this opportunity of outlining Rantec's broad level of design, development and production capability.

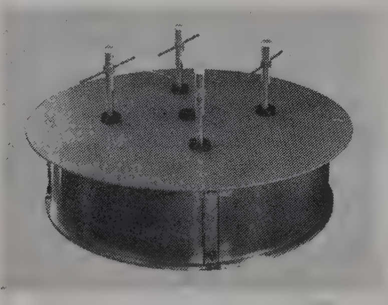
S-Band monopulse tracking feed,
integral L-band monitoring dipole

Antenna Feed Systems

Rantec feed assemblies are used on parabolic tracking and acquisition antennas ranging in size from 10 to 85 feet.

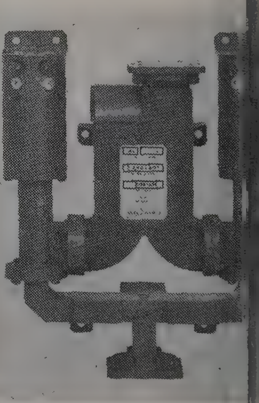


larly polarized simultaneous
g feed – 890 Mc and 960 Mc

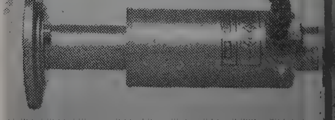


400 Mc remotely controlled
rotatable linearly polarized tracking
feed – hybrid assembly – drive

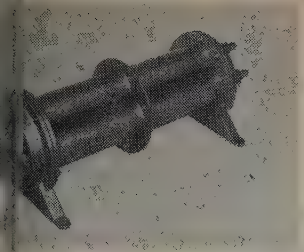
X-band
high speed switch



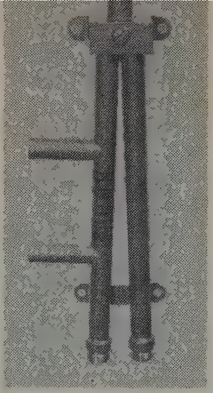
X-band single
sideband modulator

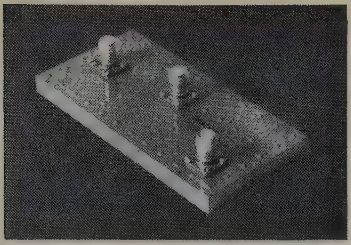


X_B-band
amplitude modulator



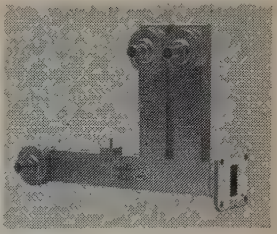
2300 Mc and 2900 Mc

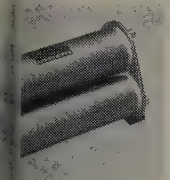




Strip line diplexing filter,
L-band and S-band

X-band
multiplexing filter



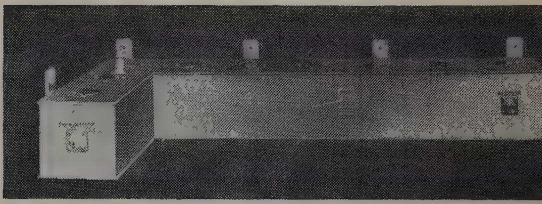


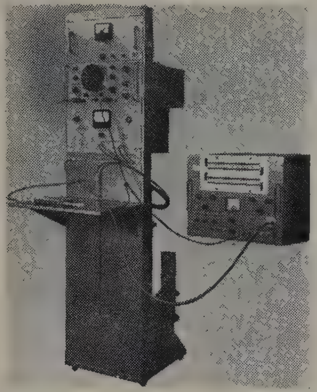
Airborne
channel multiplexer

Filters

In addition to the units shown, Rantec has developed many othe filters for special applications. An impressive staff of engineers is available to handle complicated "state-of-the-art" problems.

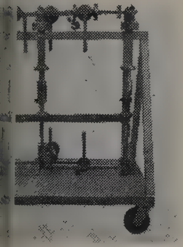
890 Mc-960 Mc high power,
diplexing filter

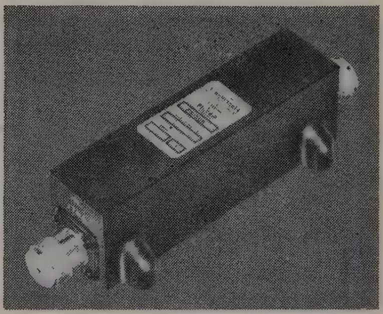




Precision microwave phase
measurement system with
automatic frequency swept display

opulse
ator

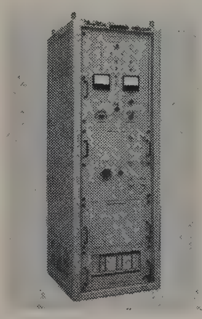




Band pass filter, 15 watt
CW unpressurized, 2200-2300 Mc

Special Test Equipment and R-F Sub-Systems

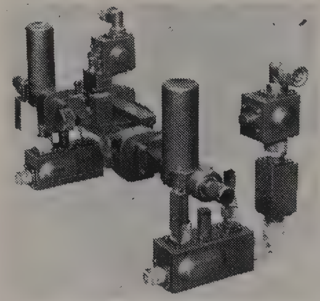
rom the number of essential microwave components available in Rantec's standard line, considerable flexibility exists for designing special test equipment, simulators and radar sub-systems.



C-band doppler simulator,
using ferrite single sideband modulator

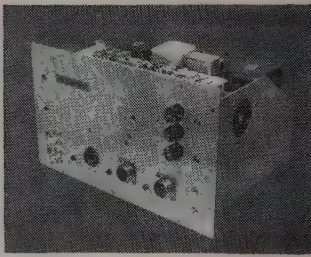
Radar
sub-system, X-band

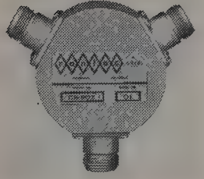
, broadband,
ator



Dual channel C-Band
parametric amplifier system

Stabilized parametric
amplifier power supply





20% bandwidth S-band
Y-junction circulator

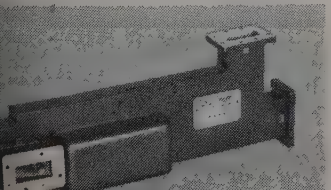
Parametric Amplifiers

Rantec's line of broadband, low insertion loss, ferrite devices and filters assure optimum performance of complete parametric amplifier systems. A variety of stable, low noise parametric amplifiers is available.

rrite Devices

variety of advanced ferrite devices is available in frequency ranges om below L-band through K-band.

These products are "typical" of Rantec's know-how, but represent only a part of the total picture. Write or call Rantec for complete product information in any of the above categories.



C-band high power

rantec

RANTEC CORPORATION
CALABASAS, CALIFORNI

NEREM 1961

The fifteenth Northeast Electronics Research and Engineering Meeting — NEREM 61 — will be held in Boston, Mass., Tuesday through Thursday, November 14-16. Sponsored by the Boston, Connecticut and Western Massachusetts Sections of the IRE, the meeting has become the third largest electronic engineering event in the nation.

Technical sessions will be held at the Somerset Hotel and at the Commonwealth Armory, at which more than 90 papers will be presented in 22 sessions, including panel-workshop day-evening meetings. Exhibits will be located at the Commonwealth Armory where millions of dollars worth of electronic equipment will be displayed at more than 400 booths.

Portions of the NEREM program of special interest to microwave engineers are reprinted as follows:

TUESDAY P.M., NOV. 14, 1961

SOMERSET HOTEL

SESSION 3: Coherent Light

Chairman: C. Shafer

Raytheon Co., Waltham, Mass.

Generation of Optical Harmonics

P. Franklin

University of Michigan, Ann Arbor, Mich.

Further Investigations on Doped Calcium Fluoride Optical Masers

P. Sorokin

IBM Research Center, Yorktown, N.Y.

Some Properties of a Gaseous Optical Maser

C. F. Luck, R. A. Paananen and H. Statz

Raytheon Co., Waltham, Mass.

Problems in an Optical Radar Design

M. L. Stich

Hughes Aircraft Co., Malibu, Calif.

WEDNESDAY A.M., NOV. 15, 1961

COMMONWEALTH ARMORY

SESSION 6: Reliability I — A Design Criterion

Chairman: I. Bosinoff

Sylvania Electric Products, Inc., Waltham, Mass.

A Survey of Techniques for Analysis and Prediction of Equipment for Reliability

H. E. Blanton

Raytheon Co., Lexington, Mass.

R. M. Jacobs

Sylvania Electric Products, Inc., Waltham, Mass.

Design Considerations for Reliable Electronic Equipment

W. J. West

Autonetics, Downey, Calif.

Predicting the Reliability of Satellite Systems

R. H. Myers

Hughes Aircraft Co., Culver City, Calif.

Reliability and Design of Electronics Systems and Equipment

F. Moskowitz

Laboratory For Electronics, Boston, Mass.

SOMERSET HOTEL

SESSION 8: Radio Astronomy I

Chairman: J. Ruze

Radiation Engineering Laboratory, Maynard, Mass.

Fundamental Requirements of Radio Astronomical Measurements

A. E. Lilley

Harvard College Observatory, Cambridge, Mass.

An Attempt to Detect the Galactic Deuterium Line Using Digital Autocorrelation Techniques

S. Weinreb

MIT, Cambridge, Mass.

Radiometric Instrumentation at Eight Millimeters

J. W. Meyer, J. J. Kirwan and D. M. Towle

MIT Lincoln Laboratory, Lexington, Mass.

The (1—cos ϕ) Radiometer

J. W. McGinn, Jr.

MIT Lincoln Laboratory, Lexington, Mass.

WEDNESDAY P.M., NOV. 15, 1961

COMMONWEALTH ARMORY

SESSION 11: Superpower Microwave
Tubes — A Panel Disc
sion on the Relative M
its of Linear-Beam a
Cross-Field Superpow
Microwave Tubes

Chairman: J. Burgess
Rome Air Development Center, Rome, N.Y.

Panel Members: T. D. Sege
Sperry Gyroscope Co., Great Ne
L.I., N.Y.
W. C. Brown
Raytheon Company, Waltham, Ma

SOMERSET HOTEL

SESSION 12: Radio Astronomy II

Chairman: P. Rizzi

Microwave Technology, Inc., W
tham, Mass.

A Broad-Band Interferometer for Studies of Discrete Radio Sources

J. N. Douglas

Yale University, New Haven, Co

**Mills Cross and Related Pencil-Be
Antennas**

G. Swarup

Stanford University, Stanford, Ca

**Electronically Scanned Radio Te
scopes**

I. M. Faigen

Chu Associates, Harvard, Mass.

S. J. Goldstein, Jr.

Harvard College Observatory, Ca
bridge, Mass.

**The Design of Radio Astronomy I
struments**

H. G. Weiss

MIT Lincoln Laboratory, Lexingt
Mass.

**Report on the 1000-Foot Spheri
Reflector Antenna**

P. Blacksmith and E. L. Bouche

Air Force Cambridge Research Ce
ter, Hanscom Field, Bedford, Ma

THURSDAY, A.M., NOV. 16, 1961

SOMERSET HOTEL

SSION 15: Atomic Frequency and Time Standards

airman: P. Bender
N.B.S., Washington, D.C.

The Cesium Atomic Beam Frequency Standard
J. Holloway
Bomac Laboratories, Inc., Beverly, Mass.

The Rubidium Optically-Pumped Frequency Standard
R. Rempel
Varian Associates, Palo Alto, Calif.

The Hydrogen Maser
D. Kleppner
Harvard University, Cambridge, Mass.

Stable Radio Frequencies for Atomic Standards
C. Searle
MIT, Cambridge, Mass.

SSION 16: University-Industry Co-operative Programs That Enable Engineers and Scientists to Keep Abreast of Latest Technological Developments — A Panel Discussion

hairman: R. M. Fano
MIT, Cambridge, Mass.

nel Members: J. Thomas
Minneapolis-Honeywell Regulator Co., Boston, Mass.
N. Marcuvitz
Polytechnic Institute of Brooklyn, N. Y.
R. Villers
Columbia University and Rautenstrouch and Villers, N.Y.C., N.Y.
J. Wolfe
General Electric Co., Schenectady, N.Y.

SSION 17: Microwave Solid-State Devices I

hairman: Glen Wade
Raytheon Co., Burlington, Mass.

Generation of Coherent Light
H. Statz
Raytheon Co., Waltham, Mass.

Microwave Modulation of Light by the Electrooptic Effect
I. P. Kaminow
Bell Telephone Laboratories, Murray Hill, N.J.

Microwave Demodulation of Light
A. E. Siegman
Stanford University, Stanford, Calif.

Parametric Amplifiers — A Status Report
R. Adler
Zenith Radio Corp., Chicago, Ill.

THURSDAY, P.M., NOV. 16, 1961

OMERSET HOTEL

ESSION 19: Atomic Frequency and Time Standards II

hairman: A. McCoubrey
Bomac Laboratories, Inc., Beverly, Mass.

Microwave Phase-Locking Systems
J. L. Altman
Laboratory For Electronics, Boston, Mass.

(*Continued on page 130*)

DIPLEXERS

AND
TRIPLEXERS

RELIABLE...LIGHT WEIGHT...LOW LOSS

The design and manufacture of missile components that exceed standard specifications is common practice at Adams-Russell. Note, for example, the characteristics of the 35 watt missile telemetry triplexer:

- ✱ 28 db isolation and 1.0 db loss at 4 Mc separation in the frequency range 215 to 250 Mc.
- ✱ Sealed units withstand shock to 100g . . . vibration at 20g to 2000 cps.
- ✱ No altitude limit.
- ✱ Ambient temperature limits of −65° to +300°F.

This triplexer can be supplied with frequency separation of 3 to 10 Mc. Mounting dimensions: 4⅛″ x 6⅝″. Weight: 54 ounces.
Write for additional information:

A R

ADAMS-RUSSELL CO., INC.
200 SIXTH STREET • CAMBRIDGE 42, MASSACHUSETTS
UNiversity 8-8040

Circle Reader Service Card 83

NEREM Schedule

(*Continued from page 129*)

World-Wide Clock Synchronization
F. H. Reder
U.S. Army Signal Research and Development Laboratory,
Ft. Monmouth, N.J.

Time Standard Requirements in Satellite Tracking for Navigation and Geodesy
G. Weiffenbach
Johns Hopkins University, Baltimore, Md.

On the General Use of Atomichrons
E. Grant
National Co., Malden, Mass.

An Atomic Definition for the Unit of Time
J. M. Richardson
Boulder Laboratories, National Bureau of Standards, Boulder, Colo.

Time Jitter and Its Measurement
R. G. Heaton
Laboratory For Electronics, Boston, Mass.

SESSION 20: Dynamics of Research and Development — A Panel Discussion

Chairman: R. L. Blanchard
Trans-Sonics, Inc., Lexington, Mass.

Panel Members: W. K. Linvill
Stanford University, Stanford, Cali
L. L. Beranek
Bolt, Beranek and Newman, Inc., ,
Cambridge, Mass.
J. W. Forrester
MIT, Cambridge, Mass.
O. T. Fundingsland
Raytheon Co., Lexington, Mass.
J. E. Storer
Sylvania Electric Products, Inc., Wa
tham, Mass.

SESSION 21: Microwave Solid State Devices II

Chairman: To be announced.

Semiconductor Microwave Contro
Devices
L. Gould, M. Bloom, R. Tennenhol
Microwave Associates, Inc., Burlin
ton, Mass.

Solid State Microwave Amplifiers
John Sie
Micro State Electronics Corp.
Murray Hill, N.J.

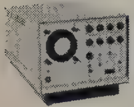
Varactor Harmonic Generators
M. E. Hines
Microwave Associates, Inc., Burlin
ton, Mass.

Another paper to be announced.

EG&G milli-mike®
INSTRUMENTS

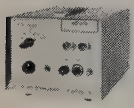
EG&G's milli-mike instruments were the first and are, by a substantial margin, the most advanced in the field of submillimicrosecond recording and measurement.

MODEL 707
OSCILLOSCOPE



DC to 2000 Mc bandwidth . . . 0.2 millimicrosecond rise time . . . single transient and repetitive signal capability . . . sensibility: 55 mv/trace width. Small spot size, maximum resolution. Six calibrated sweep speeds: 5, 30, 100, 300, 1000 and 3000 millimicroseconds/cm. Easy to operate invaluable for measurement of diode recovery time, ultra-high-frequency phenomena and in many other applications.

MODEL 751
PULSE GENERATOR



All solid-state, transistorized, high-speed pulse generator produces positive pulses of fast rise time (less than 1 millimicrosecond). Repetition rate: 10 cycles to 100 kc. Output pulse width: 2 to 100 millimicroseconds. Pulse amplitude: 20 v. into 50 ohms approx. Operable in any position. Price: $285.

MODEL 850
CAMERA SYSTEM
Optimized, fully integrated system for photographic recording of the fastest transients at 1:1 magnification.

DIODE RECOVERY
CABLE SYSTEM
Model 760, a complete system for accurate observation and measurement of diode recovery time in the millimicrosecond region. Controls and meter on front panel of sturdy metal case.

PULSE INVERTERS
Model TR-6 — coaxial-ferrite balun with excellent frequency response for converting 50 ohm single-ended to push-pull 100 ohm signals. Model 819 (for use with EG&G Model 751 Pulse Generator) to provide negative pulse output.

RADIATION
MEASUREMENTS
Complete systems using EG&G detectors and Model 707 Scope . . . available for measurement of high-frequency pulsed radiation.

TRANSFORMERS,
POWER SUPPLIES
EG&G is outstandingly well staffed and equipped to design and produce custom-built transformers, chokes, magnetic amplifiers, DC to DC converters, pulse transformers and power supplies for military or commercial use . . . and trigger transformers for all types of flash tubes.

Full technical information on all products available on request.

EG&G Edgerton, Germeshausen & Grier, Inc.
174 BROOKLINE AVENUE, BOSTON 15, MASS.

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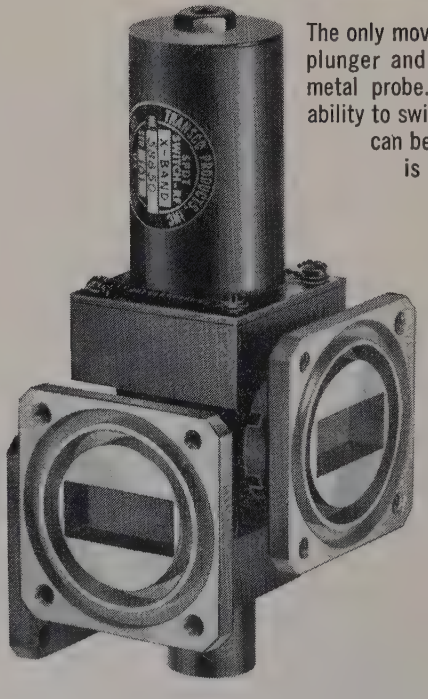
PROBING THE "TRANSPROBE" WAVEGUIDE SWITCH



The only moving parts of the "Transprobe" are solenoid plunger and a light weight, dielectrically supported metal probe. Result . . . greater flexibility, longer life, ability to switch under full waveguide power. The design can be applied to any waveguide size. Unit shown is a single-pole-double-throw, X-band switch. The design is equally successful for adaptation to SPDT, SP3T, transfer switch or special configurations. Typical specifications: Frequency . . . 8.2-12.4 KMC, VSWR . . . 1.20, Insertion Loss . . . 0.2 db, Crosstalk . . . 35 db, Life . . . 2,000,000 operations. To probe more thoroughly the unusual advantages in this new approach to waveguide switching write Transco Products, Inc., 12210 Nebraska Avenue, Los Angeles 25, California.

TRANSCO

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ITT Federal Laboratories, a division of International Telephone and Telegraph Corporation, is engaged in research, design and development of a variety of highly advanced electronic communication systems. Our programs in this area have reached a point which dictates the addition to our staff of experienced, competent engineers capable of contributing initiative and original thinking.

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- Microwave Antenna Design and Testing

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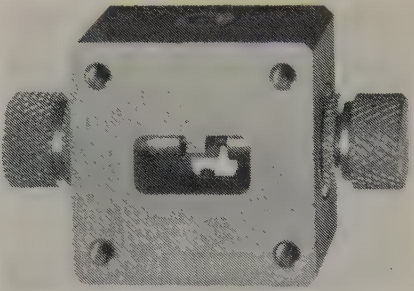
New Products

(*Continued from page 123*)

VARIAN ANNOUNCES KU-BAND ORTHOMODE® MIXER



A Ku-band Orthomode® Mixer covering the frequency range of 13.3 to 13.7 kMc has been introduced by Varian Associates, Palo Alto, Cal.

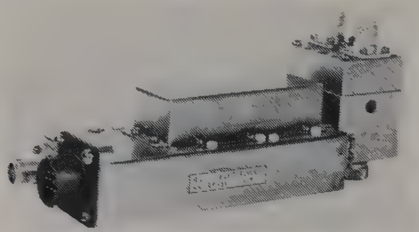
The V-8312 is of particular interest for airborne radar receiver balanced modulator applications where packaging and weight are important considerations. It is 1-5/16 inches by 1-5/16 by 3/4 inch in size and can be supplied at a weight of under two ounces. Maximum noise figure for the V-8312 is 10 db at 13.5 kMc. The noise figure includes noise contribution of 1-1/2 db 30 megacycle IF strip and a three db allowance for image frequency.

The mixer presently uses a matched pair of IN78 crystals. The signal and local oscillator input VSWR is less than two to one over a 500 megacycle bandwidth. The V-8312 uses waveguide inputs and both the LO and the signal ports mate with a UG-419 flange. The IF output which connects with a Microdot jack can be adapted for BNC connector. Terminals are provided to monitor crystal current without additional filtering.

Circle Reader Service Card 130

— *m w j* —

COAXIAL RF FRONT ENDS OPERATE FROM 250 MC — 7 KMC

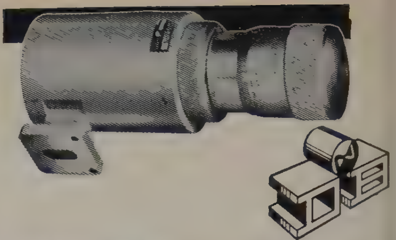


A line of coaxial rf Front Ends (Mixer-Preamplifier Assemblies) designed for operation from 250 Mc — 7 kMc has been announced by R L C Electronics, Inc., Mamaroneck, N.Y.

The coaxial mixer-preamplifier assemblies, Series RF, utilize a balanced mixer and a 30 Mc IF preamplifier and permit octave bandwidth coverage with a minimum of LO power and a maximum of LO isolation.

Series RF coaxial units are available in the following frequency ranges: 250-500 Mc, model RF-U1; 500-1000 Mc, model RF-U2; 1-2 kMc, model RF-L; 1.7-2.4 kMc, model RF-SL; 2-4 kMc,

(*Continued on page 133*)



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CAVITY
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—*gas filled for*
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Accuracy is so high these instruments may be used as secondary standards. Units are unaffected by changes in humidity, altitude or barometric pressure. Only 12 sizes serve from 2.6 KMC to 140 KMC. You save budget money on the number of sizes needed. Literature on request.

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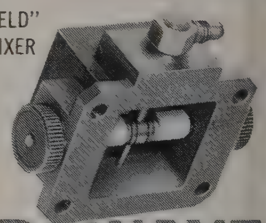

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(*Continued from page 132*)

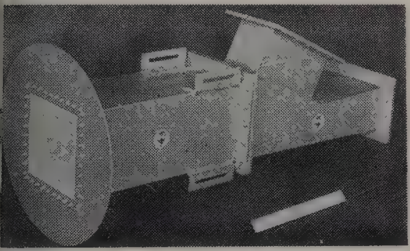
odel RF-S; and 4-7 kMc, model RF-C. Noise figure of 7.5 db maximum with overall bandwidth of 8 Mc, and a power gain of 20 db assure the user of a ceiving system whose characteristics are determined so that no special circuitry required in the main IF amplifier.

Circle Reader Service Card 131

— *m w j* —

ANTENNA SYSTEMS OFFERS COMPLETE LINE OF DUAL POLARIZED HORNS

Antenna Systems, Inc., Hingham, Mass., ow offers a complete line of dual olarized horns in all standard wave-uide sizes from WR-430 through WR-300. They are available with wave-guide inputs, or one or two coax in-uts.



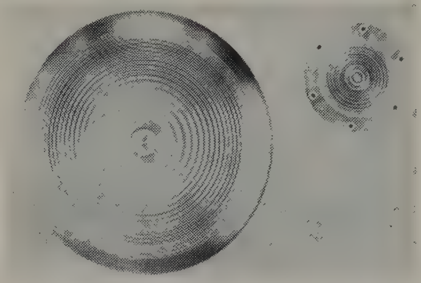
The horns feature a VSWR of less than 1.2 for 30 per cent of the frequency band. The de-coupling between inputs is greater than 30 db, and the standard aperture for f/d ratio is between 0.35 and 0.50 but other apertures are available upon request.

The units are weatherized, can be pressurized and/or anti-iced, and come equipped with mounting brackets as per customer requirements.

Circle Reader Service Card 132

— *m w j* —

FRESNEL ZONE PLATES NOW USED AT MILLIMETER WAVELENGTHS



Fresnel Zone Plates, which have been used in the past at optical frequencies, are now available from the Research Division of Electronic Communications, Inc., Timonium, Md., for use at millimeter wavelengths.

The phase-correcting plates produce focusing and collimating effects similar to those of conventional parabolic reflectors and dielectric lenses.

Fresnel Zone Plates offer the following advantages over conventional lens and parabolic reflectors: low loss, light weight, economical, large aperture, frequency range 70-3000 Gc. In production quantities zone plates can be molded; this would result in uniform antennas at low cost.

Circle Reader Service Card 133

— *m w j* —

BOOK REVIEW

SATELLITE ENVIRONMENT HANDBOOK by Francis S. Johnson, Ed., Stanford Univ. Press, 151 pp + 3 index + xii (*$5.50*).

Because most of the outer space environment that we understand, the radiation belts, earth's upper atmosphere, and geomagnetism, are phenomena associated with earth, this book might have been called a space geophysics handbook. In fact, there is an appreciable overlap with the USAF ARDC Handbook of Geophysics (MacMillan Co.) and it will be interesting later on to compare this ARDC handbook with the Satellite Environment Handbook. The latter is not a handbook in any sense of the word: handbooks are usually of many pages, this book is short; handbooks are primarily collections of data, this book is weak on data; handbooks are usually aimed at the more practical aspects of engineering or physics, this book neglects the effects of the space environment. Most equations in the book are given without derivations; a familiarity with heat, light, and electricity and magnetism is assumed. The weakest facet of the volume is insufficient depth in the expositions. Sometimes elementary explanations are needed: the book uses but does not define such terms as spectral irradiance (called radiance in a different chapter), the solar constant, and

(*Continued on page 134*)

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RF FREQUENCIES TO ±0.03%

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NOW you can get direct-reading convenience **plus** extreme precision of tuning **plus** broad frequency coverage . . . **without using tables or calibration charts.**

Only DATA-DIAL (patented) direct-reading wavemeters bring you these advantages. The tuning knob drives a long tape carrying a sloped frequency scale, which moves behind an index curve accurately drawn on a transparent window. As the cavity is tuned, the moving intersection point of these curves compensates for inherent variations, giving the frequency for each setting without further correction.

Model 3102 covers frequencies from 900 to 2100 mc, with a direct-reading accuracy of ±0.03% below 1700 mc and ±0.05% above that point. The cavity has an integral crystal detector output. Model 3103, in final development, covers frequencies from 2350 to 3750 mc. Other models will extend the range of this new line to further bands.

WRITE TODAY for more information on this and other new GCC developments in microwave components, pulse power calibrators, attenuators, oscillators and test sets.

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HIGH POWER CONTINUOUSLY VARIABLE FLAT ATTENUATOR

MODEL AB-1

The Model AB-1, the latest development from Merrimac Research and Development, Inc., is a flat high power, octave wide, continuously variable attenuator. It is capable of withstanding unusually high average powers.

- 500 to 1000 Mc
- Attenuation range: 20db min.
- Variation: less than ±5% in db at any attenuation level over the frequency range

The unit has a low initial loss, under 0.5db, and low VSWR, under 1.5:1. It will operate to 50 watts of average power without fins, and with fins added it will withstand 200 watts of average power.

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Book Review

(*Continued from page 133*)

gegenschein. Elsewhere, the explanations are too brief, especially considering the wide range of topics covered, and the concomitantly varied readership. Very distressing is the sparseness of references to background and expository material.

The chapters are eight in number and cover, in order, the upper atmosphere, ionosphere, radiation belts, solar radiation, micrometeorites, radio noise, thermal radiation from earth, and geomagnetism. The book suffers from the common problem of collections: some chapters are excellent, and some are poor. Not surprisingly, the first chapter, by the editor, is one of the best. Johnson presents new "model atmospheres," isothermal in a range around 500 km (the start of the exosphere). The change in atmospheric constituents at high altitudes with sunspot cycles is pointed up, with temperature, density, pressure, and particle density tabulated vs altitude for both sunspot maximum and minimum. In comparison the ARDC handbook (which is a more typical handbook) is short on physical explanations but contains a wealth of atmospheric detail supporting the 1959 ARDC "model atmosphere."

The ionosphere chapter is limited to a phenomenological description of the structure and gross properties. The portion on the protonosphere and whistlers (above 1300 km) is the best of this chapter. The work implies that electron densities at altitudes above the altitude of maximum electron density are known fairly well; experimental evidence does not support this. References to works which might help the reader gain background knowledge are especially sparse in this chapter. The ARDC handbook offers a wealth of engineering detail for the user of the ionosphere. Radiation belts are covered in a chapter entitled 'penetrating radiation,' and this is another very good chapter. Outstanding is a detailed chart giving particles, fluxes, and energies, with commentary. The solar radiation chapter is good in broad scope but suffers in comparison by presenting a relatively small amount of data. Micrometeorite and meteor coverage is good, considering that the totality of our knowledge on these subjects is not large. Results of micrometeorite measurements from several space probes including Explorer I and Vanguard III are presented. The meteor data is similar to that in the ARDC handbook with the latter somewhat more extensive.

The chapter on radio noise, a subject posing intriguing physical questions as well as being of great practical importance, is quite disappointing. The relation of low radio noise temperature to maser and parametric amplifier systems is only casually referred to. No formulas are given or derived for assessing the noise temperature of an antenna, earth- or space-borne. Important papers such as Hanbury Brown on a physical model for galactic radio emission, Mayer on planetary radiation temperatures, and Hogg on low noise antennas are not referred to. Radiometer techniques are summarily mentioned without any clues as to what a Dicke radiometer is or is to be used for. Here also the references are sparse. Atmospheric effects, from earth, or from space, are not discussed.

The chapter on earth thermal radiation is also abbreviated. In its favor, however, two terms, albedo and airglow, are defined. The excellent chapter on geomagnetic field is very detailed, giving earth field maps and a spherical harmonic analysis. The harmonic analysis techniques, used by Gauss in the last century, are still under improvement; several papers have appeared in the post-war period. Recent data are given on the field above the earth, including transient effects of the solar wind, storms, and hydromagnetic waves. The ARDC book contains more data, but no harmonic analysis.

Finally, an appendix contains three types of data. Planetary data include maximum, minimum, and AU distances; orbit eccentricity, inclination, and mean radius; mass; visual albedo; surface temperature; and period. Second, a list of satellites and pertinent data is included for those not reading Missiles & Rockets magazine. Third, a list of physical constants and conversion factors is given. This list is completely out of place in a book of this type which gives a minimum of definitions and background material. Any reader able to understand the material will have many sets of constants and conversion factors on his bookshelf.

In summary, the usefulness of the book is closely related to the needs and background of the reader. The book will give a good over-all picture of the various parts of space environment, and of the mechanisms and relationships involved in each. To fully utilize the book requires an appreciable background knowledge. The index is barely adequate and could profitably be longer. Those readers involved in experiments imbedded in space will find the ARDC handbook much more useful, and liberally supplied with data.

Reviewed by
R. C. Hansen
Associate Editor
the microwave journal

—*mwj*—

NEW LITERATURE

ANECHOIC CHAMBER DESIGNS DESCRIBED IN BROCHURE

A brochure describing 14 new mi-owave anechoic chamber designs is ailable from Emerson & Cuming, Inc., nton, Mass.

Chambers are described for boresight, tenna pattern and special purposes. zes shown range from in excess of 100 et long to as small as 40 feet. New enneering data is given describing relts of radar cross section measurements several of the eccosorb anechoic ambers.

Circle Reader Service Card 134

—mwj—

ATALOG GIVES DATA ON MORE HAN 200 PRECISION MICROWAVE COMPONENTS

An eight-page, two-color catalog ised by Microwave Components and ystems Corp., Monrovia, Cal., gives mplete data on over 200 standard presion microwave components, covering range from 1.70 to 40.0 gc. All units re calibrated on instruments traceable the National Bureau of Standards.

Included in the text are dimensioned rawings, photos, and electrical and mehanical specifications of types includg ferrite devices, precision low-power terminations, directional couplers, standard gain horns, and detector mounts.

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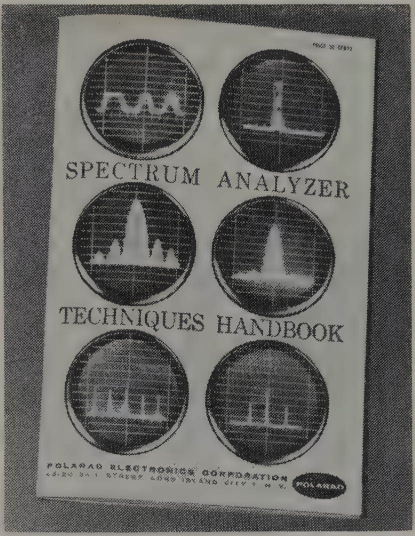
—mwj—

POLARAD OFFERS SPECTRUM ANALYZER TECHNIQUES HANDBOOK



Polarad Electronics Corp., Long Island City, N.Y., is offering a new edition of its Spectrum Analyzer Techniques Handbook. Now in its third printing, this booklet offers detailed measurement techniques using the spectrum analyzer, along with a history and general theory of operation of these versatile instruments.

A portion of the handbook describes and lists the specifications and applications of Polarad Spectrum Analyzers currently available including the new lightweight, transistorized, model SA-84T.

Circle Reader Service Card 136

—mwj—

SYLVANIA CATALOG LISTS CHARACTERISTICS OF FERRITE DEVICES

A catalog which lists the mechanical and electrical characteristics of a variety of ferrite devices including a dc-block, tee circulators and waveguide and coaxial isolators, has been announced by Sylvania Electric Products Inc., Mountain View, Cal.

R. A. Stonesifer, product sales manager of Sylvania's Microwave Device Division, said the new catalog contains the model numbers, frequencies, isolation and insertion loss, VSWR, power levels, dimensions and prices of more than 50 ferrite units.

Included in the catalog is information on devices that operate in the one Gc to 21 Gc frequency range, according to Mr. Stonesifer. Isolation as high as 80 db, and insertion loss as low as 0.2 db are reported, he added.

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—mwj—

(Continued on page 141)

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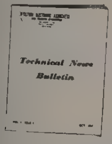

— Representing —
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Quantadyne — Los Angeles, California
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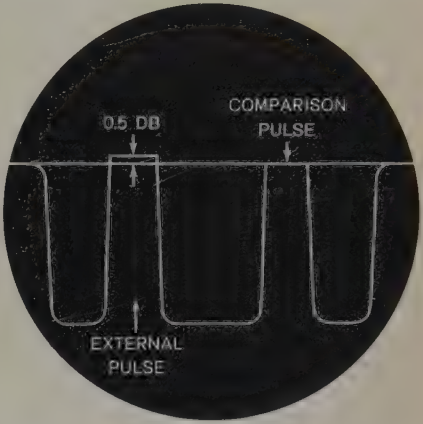
DETERMINE
PEAK PULSE POWER WITHIN 0.5 DB



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The Series 5000 Pulse Power Calibrator is the only instrument that will give a final, direct reading of peak rf pulse power to this degree of accuracy . . . quickly, regardless of waveshape, and without introducing unknown errors. In addition, it provides multiple-band coverage, through the use of interchangeable rf heads.

RF Unit Model 5205, now available, covers the range from 8500 to 9600 mc. Other rf heads, in development, will cover further important bands. The display, essentially a notch wattmeter, permits comparative power discrimination within less than 0.1 db. Direct input power level range is approximately −5 to +63 dbm.

WRITE TODAY for more information on this and other new GCC developments in microwave components, wavemeters, attenuators, oscillators and test equipment.

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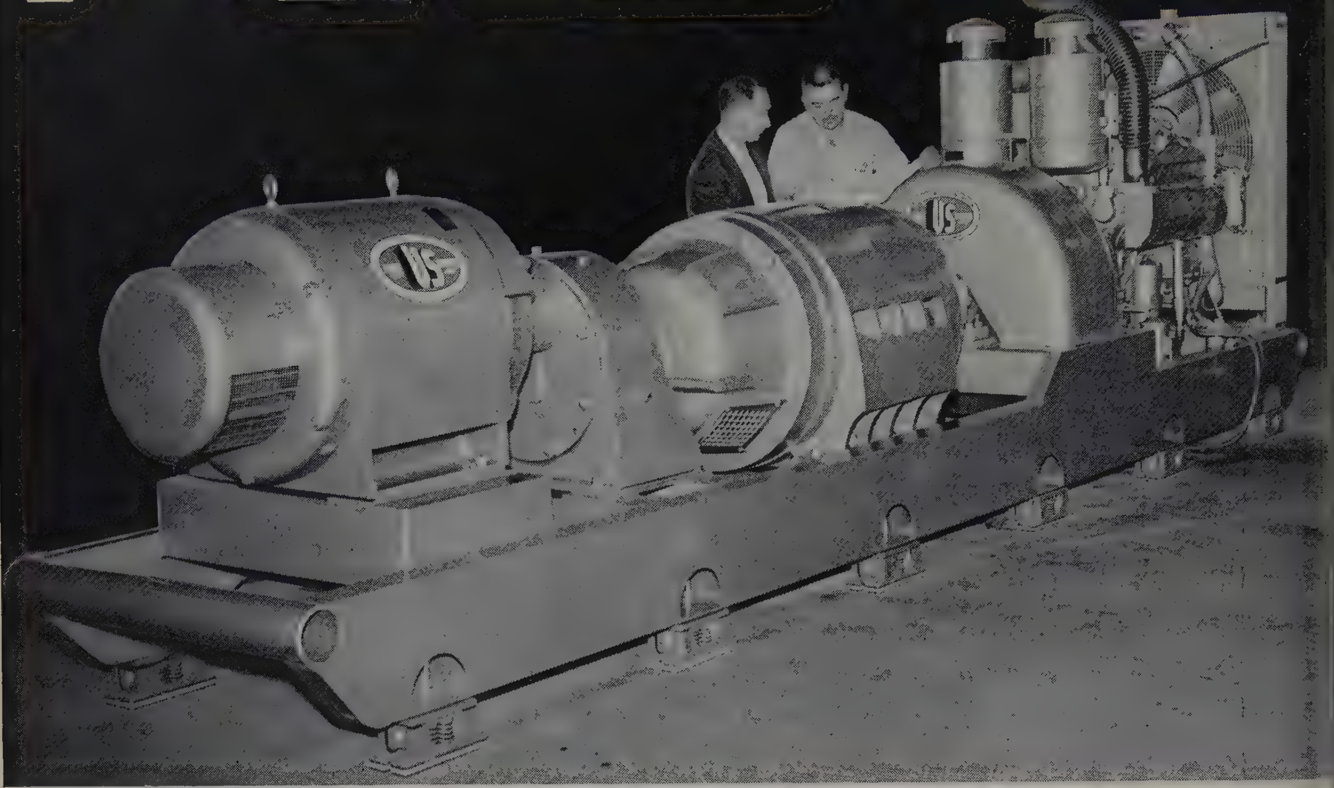
NEW



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- ★ incoming 50 cycle frequency automatically converted to 60 cycle output frequency when desired.
- ★ ultimate for stabilizing incoming variations of voltage and frequency.

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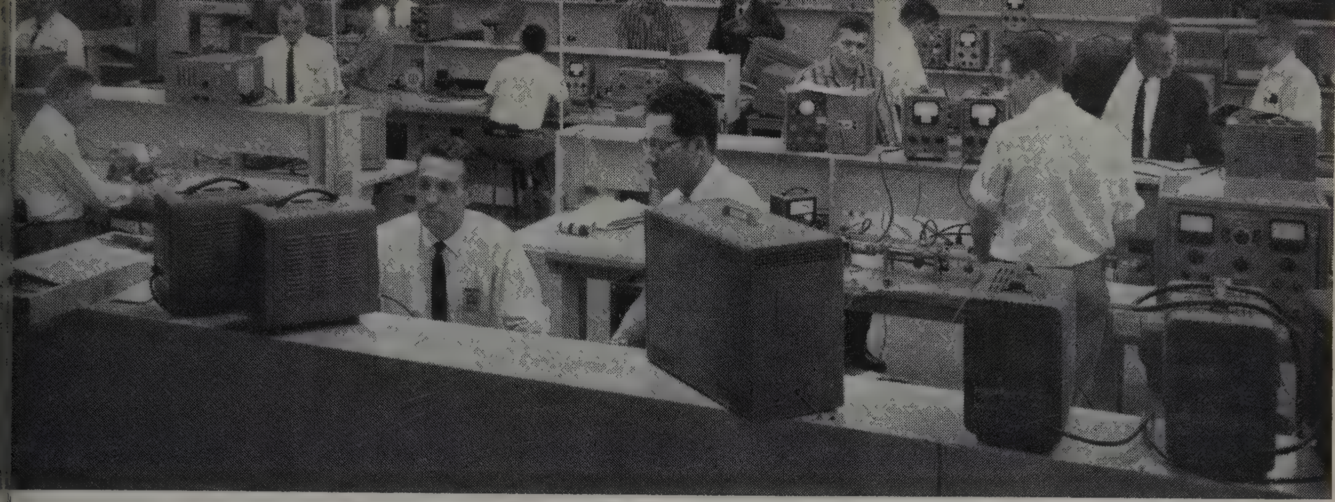


A partial view of Kearfott's engineering laboratory.

COMPANY PROFILE

KEARFOTT DIVISION

General Precision, Inc.

MICROWAVE BRANCH

Van Nuys • California

The activities of Kearfott Division, General Precision, nc. have been geared towards production and the cusomer, yet a strong element in its operational doctrine is mphasis on research and development. Founded in 1917 s an independent company, later becoming a division of General Precision, Inc. of Tarreytown, N.Y., the firm has placed greater and greater reliance on R and D for the nswers to lagging markets, the need for new and better quipment, and for the solutions to customer problems.

History

Kearfott's Microwave Branch in Van Nuys, California was founded in 1954. For the first year and a half it manufactured electrical and microwave equipment. As Kearfott's microwave capability grew, however, and customers demanded more of its products, it began manuacturing for the general market. This was in 1956, the first year of Branch operation.

General Manager Willard A. Hughes was then a project ngineer in charge of microwave development· He had ome to Kearfott from Hughes Aircraft where he had erved for five years as section head of the electronic ountermeasures group.

"That was the year we began R&D efforts on microwave errite devices," Hughes observes. "I remember it clearly because we introduced several new concepts and techniques at that time like employing wide-slab tapered field geometry, the ferrite matching step, and geometric resonance. This enabled us to produce devices that operated at twice the efficiency of those of our closest competition."

That year, 1956, saw Kearfott's ferrite products boosted into the forefront of the field through the imaginative exploitation of new markets and advances in the state-of-the-art.

In 1957, R&D efforts were redoubled and gross sales climbed. Realizing the enormous potential in microwave ferrite devices, management expanded the product line and went into microwave subassemblies, antenna production for Nike missiles, and began manufacturing a two-dimensional slot-array antenna used in Doppler navigational systems.

A better time for expansion in the field of microwave ferrite devices could not have been chosen. This was the year of Sputnik I, and under the stimulus of Russia's competitive threat, the nation's military program went into high gear and absorbed microwave ferrite devices in ever-increasing quantities.

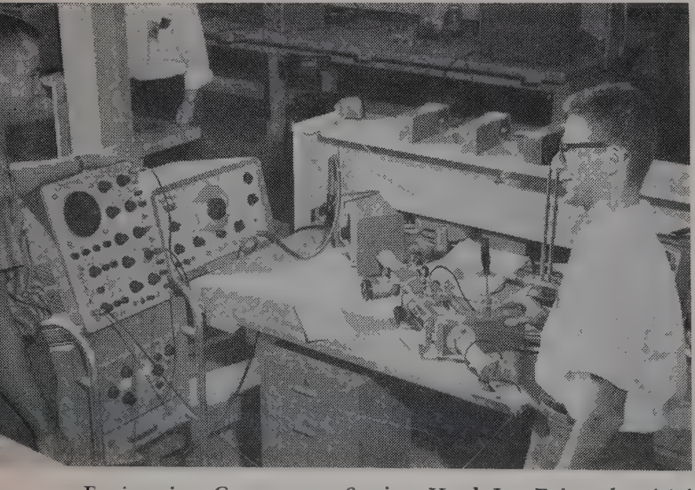
The following year, 1958, Kearfott's Microwave production department introduced new methods of large scale manufacture and applied advanced methods of fabrication and production. This enabled the company to slash the cost of many products, and accelerated the process of turning out microwave ferrite isolators, phase shifters, amplitude modulators, and ferrite switches. Because of the staff's wide experience in the production of amplifiers, exciters, drivers, modulators, power supplies and spectrum analyzers, they were led to the development of X- and L-Band transponders and interrogator systems incorporating stripline, coax, and waveguide design techniques.

At one of Kearfott's weekly management committee meetings, General Manager Bill Hughes discusses the dip-brazing and prod tion techniques involved in the production of Kearfott's monopulse radar RF subsystem. With him, (left to right) are: Comptrol Fran Hall; Assistant General Manager George Nalesnik (also standing); Chief Engineer Norm Weinhouse; Sales Manager Jo Becker; and Production Manager Bob Allan.

At the same time, the Microwave Branch developed a reliable X-Band Beacon System designed especially for marine range applications. The beacon incorporated highly advanced electronic and mechanical design features. The unit employed ferrite antenna switching and ferrite modulating techniques applied directly in the high power r-f waveguide. The opportunity then arose for getting into the development phase of making Air Traffic Control transponders. This involved work with strip-line duplexers, cavity preselectors, strip-line balanced mixers, I-F amplifiers, and pulse modulators.

All of these developments were instrumental in furthering Kearfott's progress into the r-f subsystems market which is now approximately 50 per cent of today's total microwave market.

A major factor in the Kearfott Microwave Branch's growth at this time was the installation of a ferrite materials facility which enabled the firm to perfect several new very low-loss ferrite materials, specifically for microwave applications. These materials gave their ferrite devices superior performance in every category to anything on the market at the time. R&D had become an ev more substantial part of management's effort to stay ahe of the field.



Engineering Components Section Head Irv Rabowsky (right) explains to a production technician the alignment technique employed in production testing of Kearfott's communications link isoplexer.

The strong R&D effort of 1958 was doubled in 19 and applied to ferrite and nonferrite microwave comp nents, coaxial components, special nonlinear ferrite c vices, strip-line components, microwave systems, and m crowave test equipment and product redesign. From th research came a series of broad-band waveguide ran isolators from S-Band to Ku-Band, and the production the first ½-inch long X-Band isolator ever built. addition, the program produced an X-Band test set i proved by the addition of an isolator to eliminate pullin and the first microsecond switches ever made.

In the course of this research, Kearfott's Microwa scientists also perfected the technique of encapsulati microwave components. An offshoot of this program w semiconductor and ferrite parametric research which pr duced a working ferrite power limiter.

The strong R&D effort, the application of advanc production and quality control techniques, and the wo of the solid state research laboratory were reflected in t increase of sales. Some of the projects which engag Kearfott's scientists and engineers during that year wer the application of basic ferrite materials for study progran involving nonlinear devices; the extended use of micr wave power limiters, parametric amplifiers, cut-off mo switches, infrared sensitive cavities, and ultra-spe switches; the development of new concepts in stripli devices; seeking new approaches to the intricate problen associated with high speed switches, circulators, modul tors, and phase shifters; the development of more a vanced ferrite materials in the radar frequency spectru the development of ferrite materials exhibiting lower i sertion loss, greater temperature stability, and linear pow characteristics; and the perfecting of new dip-brazi techniques.

In 1960, sales climbed again despite the general busine recession. Sales at this time were mostly in test equi ment, ferrite devices, waveguide components, antenn subsystems, and job-shop dip brazing.

Although general business in this area had dropped off, e company had a substantial backlog which helped susain a high level of activity through the first quarter of 961. Kearfott Microwave's management now had an pportunity to tighten operations all around by streamning operations and strengthening the product line.

"The entire program of exercising more stringent uality control and tightening up on production methods, as already paid dividends," says George Nalesnik, Asistant General Manager.

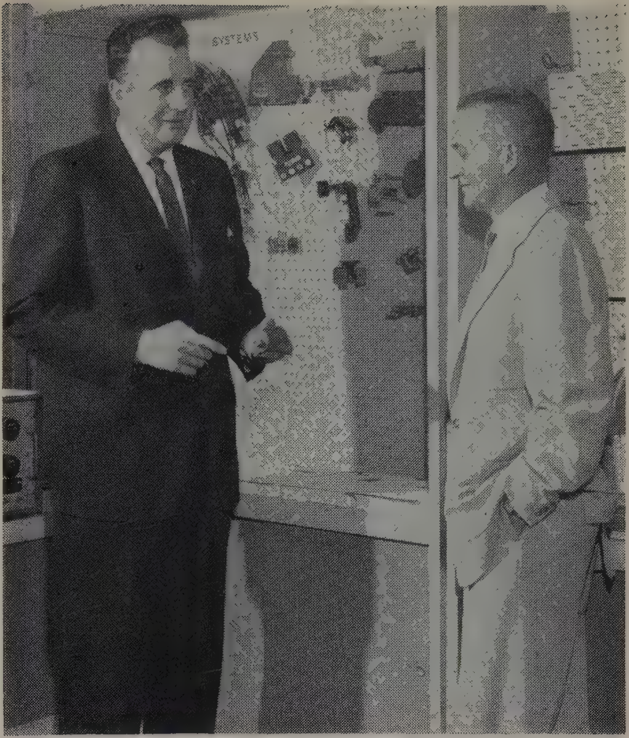
"Kearfott Microwave is organized around the concept f project engineer responsibility for a job from concepion to final shipment and after," he says. "We have ound that this isolates responsibility, permits accurate eedback of information on the product's behavior in the eld, and gives the customer a focus of accountability when e wants to know what to do, what went wrong, or how o make the product better. The next time the project ngineer designs something, he builds the fixes into it."

urrent Activities

At the moment, Kearfott is working on microsecond errite switches and millisecond semiconductor ferrite witches and is promoting its line of notch rejection filters, xtremely small light-weight isolators, and a complete ine of variable bidirectional couplers with plus or minus ne db accuracy. The couplers are completely reactive, do ot absorb energy, and can be used on high-powered ECM (electronic countermeasure) programs.

Also included in current activities is work on a complete line of waveguide coaxial isolators covering complete frequency bands; mechanical waveguide switches; hase modulators using plated fibre glass waveguide techniques; and a complete line of strip-line mixers covering ctave band widths, cutoff mode switches, and a new isoplexer which is a single frequency isolator for use in existing microwave communication links to prevent phase distortion and intermodulation.

"Since military specs are becoming tougher all around, including tests of temperature and humidity, shock and vibration, and an extremely wide range of temperature, a good portion of this year's R&D activities has been spent in perfecting inherently wide-temperature ferrite devices operating from −55°C to +125°C," says General Manager Bill Hughes. "I think we're well on our way to producing what is needed in this area."



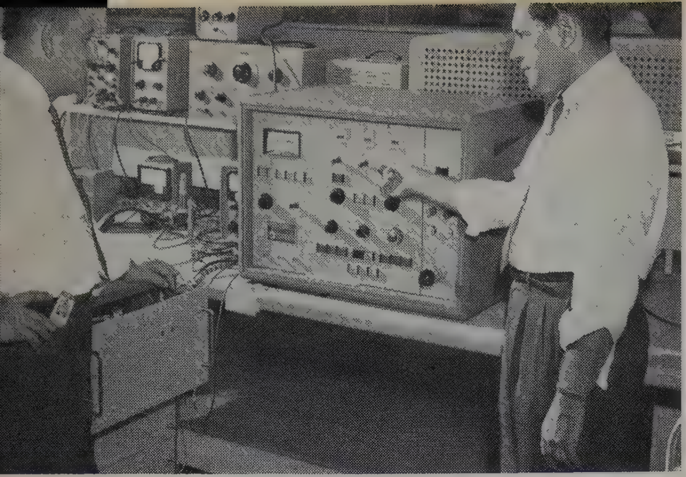
Sales Manager John Becker (left) stands before Kearfott's sales display board with Customer Service Supervisor Paul Boone discussing a new product line.

One component which demonstrates this wide temperature capability is the circulator T ferrite switch which operates from −55°C to +125°C with an insertion loss of only 0.2 db and greater than 24 db isolation used in commercial weather radar.

Some of Kearfott's current activity in Van Nuys centers around its dip brazing shop where outside work is done on a contract basis. This ultramodern facility is designed to accommodate the most demanding requirements of precision aluminum dip brazing fabrication. The most recently developed techniques are used to assure economical quality production, and the Van Nuys engineering and production staffs are available to assist in the planning and tooling of particularly complicated brazing jobs for military and commercial users.

This shop is under the direction of Production Manager Bob Allan, formerly of Cascade Research and Hughes

Partial view of Kearfott's machine shop facilities.



Assistant Manager George Nalesnik (left) discusses Kearfott's K_u Band remote control transponder test set with Engineering Section Head Lloyd Cohan.

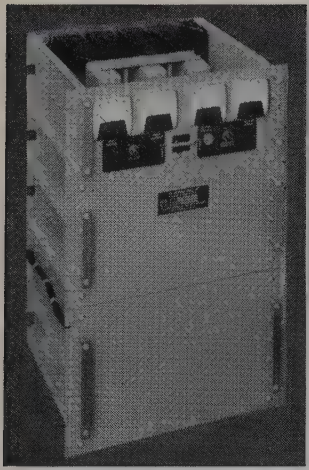
Aircraft. "We set the shop up in an attempt to become self-sufficient, and we've realized a dozen unexpected benefits from it. It has certainly brought our costs down," Allan says. This statement reveals one of the major facets of Kearfott Microwave management's thinking: cost control.

Kearfott and its Microwave Branch is a production-oriented company which nonetheless, as a matter of self-interest, puts great emphasis on R&D and quality control. As evidence of the success of this mix in practical applications, Hughes points out that Kearfott Microwave is now in the middle of a manufacturing and research program which will make possible the delivery of microwave components in a week to ten days from the time o order . . . and at perhaps 50 per cent less cost then current competitive prices.

Hughes and his management team agree that the us of microwave techniques will expand tremendously i tracking and guidance systems, satellite communication communications in outer space, in data links for TV an telephone, and in commercial and industrial uses lik microwave ovens, heating and drying, and in medical therapy.

Though the Microwave Branch and its activities ar closely meshed with Kearfott proper, the Microwav Branch operates in a sense as a separate company. "Th helps maintain the happy blending of small company a mosphere and flexibility where individual talents ar recognized and given free scope for development, whil retaining the advantages of association with a large corporation with national sales, marketing, and distributio channels, and tremendous financial resources," says Nalesnik.

In a memo to company personnel, Gen. Mgr. Hughe said: "The Microwave Branch has never been in as goo condition as it is right now. Our engineering department is well-staffed, and our production department i headed by individuals who constantly think of ways t reduce costs and increase production. We will make 196 a profitable year in spite of the generally low volume o the microwave market. And when the full potential o the microwave industry does materialize, we are in position to grow rapidly with an expanding industry."



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(*Continued from page 135*)

BROCHURE DESCRIBES "OFF-THE-SHELF" PCM TELEMETRY

An "off-the-shelf" PCM telemetry system is described in an eight-page illustrated brochure available from Radiation Incorporated, Melbourne, Fla.

The brochure describes PCM evolution and the many applications of Radiation's PCM technology, citing in-use systems employed by GE, Thickol and Norair. It also presents a review of the PCM systems designed and built for the Holloman sled program, Titan inertial guidance R&D, and Minuteman ICBM.

Brochure Specs on Model 1323, the first "standard" PCM telemetering system offered by Radiation, include information on reliability, bi-level programming, inputs for processing, inputs for control and synchronization, and outputs.

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—*mwj*—

STRAND BULLETIN CONTAINS MICROWAVE SIGNAL GENERATOR SPECIFICATIONS

A technical bulletin containing condensed electrical and mechanical specifications for 17 different stabilized microwave signal generators is now available from Strand Labs, Inc., Newton, Mass.

As described in the illustrated two-color bulletin, the Strand Labs stabilized microwave signal generators are available in models covering the frequency ranges from the L-Band (1.0-2.0 kMc) to the Ka-Band (32.0-37.0 kMc). Short-term frequency stability for most models is within 0.01 ppm, and long-term frequency stability within one ppm.

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—*mwj*—

MICROWAVE TUBE CATALOG AVAILABLE FROM RAYTHEON

A 70-page microwave tube catalog is now available from Raytheon Company's Microwave & Power Tube Division, Waltham, Mass.

The catalog lists 201 active, unclassified microwave tubes of all types, as well as ferrite devices, magnetic components, high power test modulators and infra-red detectors.

Fully illustrated, with detailed, descriptive "specs" on each listing, the catalog is color-tabbed for sections including magnetrons, klystrons, amplitrons and stabilotrons, backward wave oscillators, traveling wave tubes, crossed field amplifiers and associated components.

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—*mwj*—

RCA APPLICATION NOTE DESCRIBES RCA-6939 TWIN POWER PENTODE USES

The application of the RCA-6939 twin power pentode in Class A rf-amplifier and frequency-tripler service at frequencies up to 500 megacycles is discussed in Application Note AN-192, published by RCA, Electron Tube Division, Harrison, N.J.

The RCA-6939 is a twin power pentode of the nine-pin miniature type. At 500 megacycles, it can deliver an average of five watts of useful power under CCS conditions and six watts of useful power under ICAS conditions. In frequency-tripler service, it can deliver an average of 1.8 watts (CCS) and 2.2 watts (ICAS) conditions.

The eight-page Note describes circuits illustrating the use of this tube in a "straight-through" amplifier stage and in frequency-tripler service.

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—*mwj*—

BROCHURE DESCRIBES METHODS OF DETERMINING RF POWER LEVELS

Weinschel Engineering, Kensington, Md., has issued a brochure on precise methods of determining RF power levels which discusses the sources of error of these methods.

The brochure entitled "RF Power Bridges and Thermistor Mounts" goes on to completely describe Weinschel's Precision Power Bridges, Thermistor Mounts and X-Band Power Standards. Accuracy of NBS test data for directional coupler-thermistor mount combinations is mentioned.

In addition, the brochure describes applications using a calibrated mount-coupler combination and power bridge for transfer of calibration factor from one mount to another; setting up an RF power standard; and measurement of an unknown RF power.

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—*mwj*—

ORTHO CATALOG PAGE ON VARIABLE RF ATTENUATORS AVAILABLE

A catalog page, describing the Ortho variable rf attenuators and containing a front view of the panel and a table of specifications for the seven different types, is available from Ortho Filter Corp., Paterson, N.J.

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—*mwj*—

(*Continued on page 142*)

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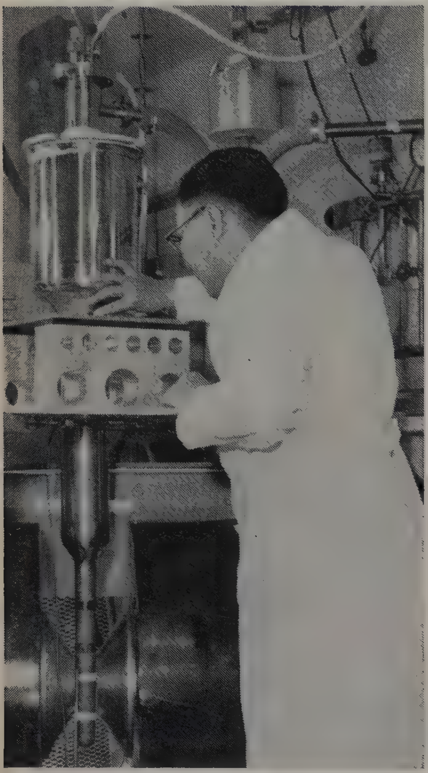

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New Literature

(*Continued from page 141*)

SIX-PAGE CATALOG ISSUED BY MELABS

A six-page condensed catalog, Number 8-61, has been issued by MELABS, Palo Alto, Cal., which provides general data and key specifications on the current line of MELABS microwave instrumentation and components.

Included is information on their new microwave sweep generators, the "LAB-CVR" laboratory receiver, and several new miniature and ultra-miniature ferrite components.

In addition, details are provided on MELABS Research and Development and Systems facilities for work in the Gc to millimeter frequency regions.

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—mwj—

CATALOGUE SHEET ON BAND PASS FILTERS AVAILABLE FROM PCA

A new catalogue sheet on band pass filters designed for the replacement of conventional filters in telemetering applications is available from PCA Electronics, Inc., Sepulveda, Cal.

Displayed in the new literature are current filters, together with their dimensions, a chart displaying Typical 7 1/2 per cent I.R.I.G. Channel, technical filter data and ordering specifications.

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—mwj—

REVISED "RESINS SELECTOR" EDITION ISSUED BY MARBLETTE

A revised edition of its "Maraset Electrical Resins Selector" has been issued by the Marblette Corp., Long Island City, N.Y.

The brochure is an easy-to-read guide to Marblette's insulating resins and their uses for potting, encapsulating, and coating electrical and electronic products, parts, and assemblies. While information has been brought up to date, the booklet's handy "double duty" format has been retained. Folded, it fits conveniently into plant or office files. It is also designed to be unfolded with its center section spread out for attaching to a wall or bulletin board.

Indicated for each resin in the listing are temperature class and thermal properties; physical and mechanical properties; pot life; type and proportion of hardener, and curing method. The clear columnar layout in which these are tabulated facilitates comparison of such characteristics as viscosity, density, shrinkage, dielectric and impact strengths, conductivity, and volume resistivity. The selector also summarizes each resin system's outstanding features, notes applications for which various resin groups are suitable, and illustrates uses.

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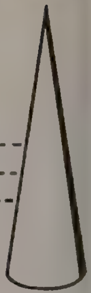

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Applied Research

Applied research to extend the state of the art for microwave interaction structures and high power electron guns, beams, and focusing mechanisms, as well as solid state microwave devices. Openings exist at the David Sarnoff Research Laboratories in Princeton, New Jersey.

Tube Product Development

Product development and applications engineering as well as test and process equipment design for traveling-wave tubes, tunable magnetrons, and pencil tubes. These tubes fill an ever increasing number of satellite, military and commercial sockets. Openings exist at RCA's Microwave Engineering Department in Harrison, New Jersey.

Solid State Development

Design and development of microwave solid state parametric amplifier devices, frequency converters and oscillators and amplifiers utilizing tunnel diodes. Openings exist at RCA's West Coast Microwave Engineering Laboratory in Los Angeles, California.

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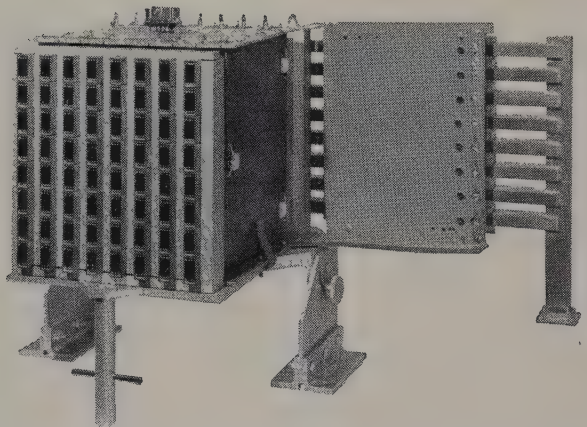

■ Requirements of new and continuing projects concerned with space vehicle communications, navigation, and radar have created new openings for electromagnetic theory specialists as well as antenna engineers. The scientists and engineers of the Research and Development Division of the Hughes Aircraft Company Aerospace Group in Culver City are providing broad scientific and technical leadership to government and company funded programs on advanced airborne and space electronic systems, air to air missiles, ballistic missiles, and satellite and interplanetary communication systems. As part of this team, the Antenna Department is responsible for a diversified program of antenna research and development in the following specific areas:

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4. Pattern synthesis from sources on arbitrarily curved surfaces.
5. Aperture control by application of solid state devices.
6. Multi-function aperture and feed capabilities.

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If you meet the above qualifications and are interested in joining other superior scientists and engineers at Hughes, please airmail your resume to **MR. ROBERT A. MARTIN,** Supervisor Scientific Employment, Hughes Aerospace Engineering Division, 11940 West Jefferson Blvd., Culver City 22, California.

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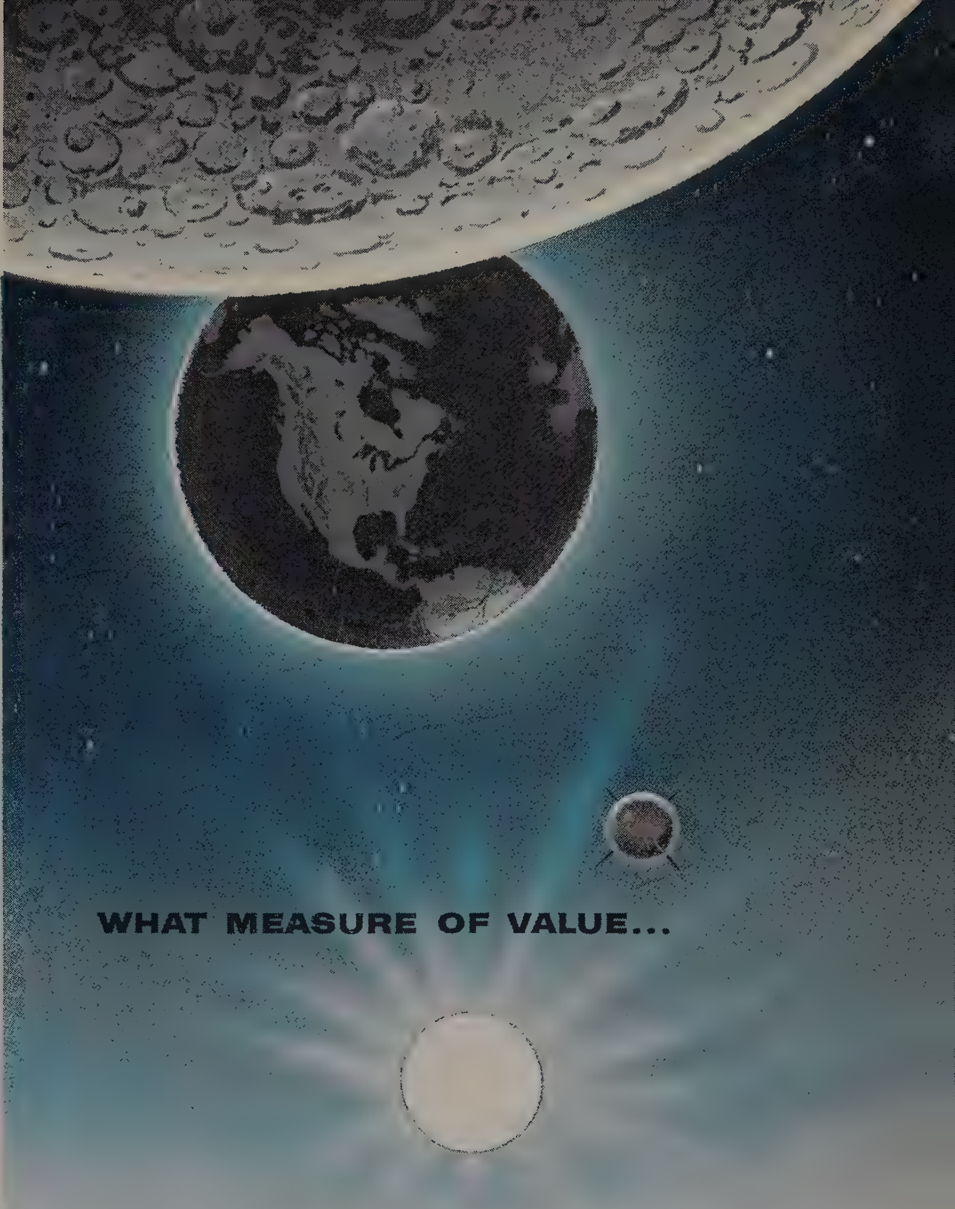
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PARAMETRIC AMPLIFIERS – BOOM OR BUST?

By JOSEPH C. GROTH, JR.

The parametric amplifier has been the subject of wide interest within the microwave industry almost from its inception. This interest began within the scientific community in 1956 and 1957, and burst into prominence with the publication of a number of papers in the June and July 1958 *Proceedings of the IRE.*

By 1959, almost every electronics company of any size or importance had a research group working on parametric amplifiers. The system upgrading to be gained through the use of parametric amplifiers was being widely heralded in the various electronics trade publications, and parametric amplifier R&D was being quoted as "one of the hottest projects to reach the laboratories in years."

An estimated 50 companies were carrying on parametric amplifier research and development by mid-1959 including: Philco Corp., Zenith Radio Corp., Microwave Associates, Inc., Raytheon, Sylvania Research Laboratories, Airborne Instruments Laboratory, David Sarnoff Research Center of R.C.A., Bell Telephone Laboratories, Sperry Microwave Electronics Company, International Telephone & Telegraph Corp., Martin Company, Stanford Research Institute, Cornell Aeronautical Laboratory, Hughes Aircraft Company, Texas Instruments, Westinghouse, Varian Associates, General Electric Company's Electronics Laboratory.

It is important to note that in many instances parametric amplifier research and development was sponsored by company funds although government funding was also provided either through R&D contracts or in-house system support programs.

The willingness of many companies to support parametric amplifier R&D out of profits can be attributed to the belief that parametric amplifiers would develop into a profitable product line.

In spite of all the publicity parametric amplifiers had received by 1959, a market in terms of buying and selling parametric amplifiers in quantity had not developed. Two companies were actively marketing parametric amplifiers i a commercial sense in 1959 — Microwave Associates Inc and Hughes Aircraft Company. Both firms marketed wha might be termed "prototype" units that year, but the tota market for 1959 is estimated to have been less than $100. 000.

1960 marked the emergence of the parametric amplifie as an identifiable product or segment of the microwave industry with a market which for the first time exceede one million dollars.

These key things occurred within the industry durin 1960:

- — Parametric amplifiers were advertised and sold fo the first time on a firm fixed price and delivery basi
- — Six new companies entered the commercial parametric amplifier market.
- — The first parametric amplifiers to be utilized i operational radar and communications systems wer delivered and began operating in the field.
- — One company dropped out of the parametric amplifier market.
- — The total parametric amplifier market (excluding research and development) in 1960 exceeded $1,000. 000. on a total volume of about 500 units.

The companies which entered what might be terme the commercial parametric amplifier market for the firs time during 1960 were: Airborne Instruments Laboratory Melabs, LEL, Radio Receptor Company, Texas Instrument General Electric.

It is interesting to note that only three of these firm were included in the list of companies believed to hav been actively carrying out parametric amplifier R&D du ing 1959. Melabs, LEL and Radio Receptor Compan being the newcomers to the listing.

One new company was formed in 1960 with parametri mplifiers as its major product line — Micromega Cororation. (This in itself an indication that the industry ad arrived.)

1960 also saw one of the pioneers in the industry — Microwave Associates, Inc. — apparently withdraw to a arge extent from active participation in the market. This move was no doubt based upon a decision to concentrate n the sale of varactor diodes — a key component in any olid state parametric amplifier. Microwave Associates is major supplier of varactor diodes to other firms in the arametric amplifier industry, and apparently did not wish o actively compete with its customers for sale of the end tem.

By mid-1960, *Electronic Week* noted the parametric mplifier "is emerging from successful tests as the microwave component of the year," and went on to say "The arametric amplifier's capability of boosting the sensitivity of a radar set by 8 or 9 decibels for $10,000. or so rouses high hopes for successful sales."

Two parametric amplifier production contracts were reponsible for pushing 1960 parametric amplifier sales over he million dollar mark:

- — Microwave Associates, Inc. received an estimated $88,000. contract from the U.S. Marine Corps for production of 28 L-Band Parametric Amplifiers for retrofit of the MPS-11 radar.
- — Hughes Aircraft Company delivered 337 S-Band Parametric Amplifiers on a contract awarded by Gilfillan Bros. Inc. during the 4th Quarter of 1959. Total dollar volume of this contract to retrofit the AN/CPN-4 and 11 radars with parametric amplifiers was in excess of $500,000. including spares.

Hughes Aircraft Company captured slightly over 50 per cent of the commercial parametric amplifier market in 1960 primarily by virtue of its AN/CPN-4 and 11 production contract. The remainder of the market was divided among the other seven companies in the market with Micromega Corporation, Microwave Associates, General Electric and Texas Instruments recording estimated sales around the $100,000. level. Melabs, Radio Receptor, LEL and Airborne Instruments Laboratory had estimated sales of less than $50,000.

JOSEPH C. GROTH, JR. is responsible for marketing Hughes Aircraft Co.'s parametric amplifier and ferrite device product lines. He has been engaged in this activity since coming to Hughes in July 1958. Previously, Mr. Groth was Executive Assistant to the President of Winzen Research Inc., Minneapolis, Minn.

Mr. Groth received a bachelors degree in journalism and advertising from the University of Minnesota in 1951, and attended the St. Paul College of Law during 1953 and 1954.

He is presently serving as a member of the board of directors of the recently formed national Electronics Sales Managers Association.

Several other interesting observations can be made about the parametric amplifier market in 1960. A portion of the cost of developing parametric amplifiers for specific systems was borne in many cases by the parametric amplifier manufacturer. The reasons behind this development are several, but certainly must include two major considerations. One, as a completely new product the parametric amplifier was subject to a certain amount of customer sales resistance. In order to overcome this resistance and add impetus to the development of a parametric amplifier market, the parametric amplifier manufacturers themselves were forced to absorb development costs in order to get the customers to buy. A second and perhaps decisive factor was the increased competition encountered by parametric amplifier manufacturers in 1960 with an attendant driving downward of prices.

In the author's opinion, it would be fair to state that most companies engaged in the parametric amplifier business in 1960 did not realize a profit on their sales. Some considered themselves fortunate to break even and others no doubt counted on swallowing a loss as the cost of entering the market. Certainly in retrospect, 1960's results were not in themselves encouraging enough to justify the amount of funds invested in the development of parametric amplifiers to date by various companies in the field. Nor did parametric amplifiers become the best sellers of the microwave industry in 1960 as *Electronic Week* speculated might happen.

This article would not be complete without at least a brief glance at the future market for parametric amplifiers. Although there are some indications that 1961 may be the "boom" year for parametric amplifiers that *Electronic Week* originally predicted for 1960, there are also some storm warnings that may mean 1961 will be a "bust" for some firms in the industry.

Several things can be said about the parametric amplifier industry in 1961 to date:

- — Six additional firms have entered the commercial parametric amplifier market in recent months — Varian, Zenith Radio Company, Motorola, Aeronca and Quantatron. This brings the total listing of current suppliers to fourteen.
- — Of the new entries, four were included in the 1959 listing of companies conducting R&D work in the field. Two — Aeronca and Quantatron have entered the field for the first time.
- — The entry of these new firms to the market place will result in increased competition and an even greater depressing effect upon parametric amplifier prices.
- — As of May 1961, orders totalling an estimated $1,500,000. had been placed with various parametric amplifier manufacturers. The total market for 1961 should exceed $3,000,000.
- — The majority of 1961's parametric amplifier sales to date have been divided almost equally between Micromega Corp., Hughes Aircraft Company, Texas Instruments and Sperry Microwave Company — a new entry.
- — Requests for proposals for new radar and communications systems from most key government agencies include provisions for parametric amplifiers.

A market survey completed by the author in August 1959 predicted that the major market for the parametric amplifier for the 1960-1963 time period would be retrofitting of existing systems with parametric amplifiers. The size of this market was estimated to be about $20 million. With the exception of the AN/CPN-4 & 11 retrofit program, this market has been almost non-existent until recently. This has been due to the lag time in the government procurement cycle for such retrofit programs. A second and major contributing factor was the length of time it has taken to convince system operators that the parametric amplifier is a useful and reliable device.

Hughes Aircraft Company has for some time pursued the marketing concept that the best way to sell a parametric amplifier was to actually demonstrate one in a potential customer's system. There is nothing unique about this idea, and the industry in general has done an excellent job of selling itself through this technique with the result that it appears the retrofit market may at last be developing.

The title of this article is "Parametric Amplifiers — Boom or Bust?" The author has touched on some aspects which may lead to a "boom," but has not yet dealt at length with the also existent possibility of a "bust."

Those companies in the parametric amplifier market in 1960 invested to an extent in financing prototype units for specific systems which they hoped would be retrofitted in quantity. At the time, it was natural to consider that this investment would be offset by the profit to be made on a production order. The entry of another group of companies to the marketplace now places this hope in a somewhat wanning light, and these predicted profits may largely disappear.

With fourteen companies in the industry and a total estimated market for 1961 of three million dollars, it is quite apparent that the size of the parametric amplifier market has not yet caught up with the number of suppliers, and price will play an increasingly important role with respect to which firm gets the business that is available.

In the author's opinion, the industry is also plagued by what to some extent are artificial prices. For small quantity orders, prices are being decided based upon an entree to a certain program's being worth taking the business at a loss. This means sale prices in certain instances bear but little relation to true costs. A second area of concern involves the fact the industry in general does not have sufficient large quantity production experience and cost history to be able to price production units with any degree of accuracy. This tends to make separating fact from fantasy somewhat of a different thing to do when quoting on a quantity production order.

Another problem which may be encountered during 1961 centers around the technical ability of the industry to deliver the goods in terms of end products which meet their specifications and operate reliably in the field. It must be remembered that parametric amplifiers are but a little over a year out of the research and development stage. The industry itself must determine what can and cannot be promised and delivered in terms of present parametric amplifier state-of-the-art. An error in judgment could not only lead to financial loss, but could seriously slow the pace of parametric amplifier marke development.

It would appear that 1961 will separate "the men from the boys" in the parametric amplifier industry. Some firms will no doubt exit from the market either by choice or by force of circumstance. Others may prosper, and still others may consider themselves lucky to be able to hold their own. Those who manage to survive will probably learn that their profits and losses vary almost as much as the parameters of the differential equation governing the operation of the parametric amplifier itself.

Although it is dangerous to speculate on what might happen more than six months in the future, several things can be predicted with regard to the parametric amplifier market in 1962 and beyond:

- — The market in 1962 will increase to at least $6,000,000. or double the estimated 1961 volume and could conceivably reach the $10,000,000. mark. This will be determined almost exclusively by the government's decisions regarding how many existing radar and communications sets should be kept in existence and retrofitted with parametric amplifiers to increase performance. The Kennedy administration's increased stress on limited warfare should favorably affect this possibility.
- — Production of certain new radar and communications systems being procured in 1961 should begin in late 1962 and 1963 with an attendant increase in the parametric amplifier market.
- — At this point, it is not clear whether the decline in the retrofit market will be taken up by the increase in parametric amplifier production for new systems.
- — It seems quite clear that at some point in time the parametric amplifier market will stabilize with parametric amplifiers becoming as much a standard part of electronic systems as mixers are today. The author would not presume to hazard a guess as to when or what volume the market will have at that point.

The increase in volume of the parametric amplifier market has had several side effects upon the microwave industry in general. In addition to establishing a new segment of the industry, it has stimulated the sales of klystrons, varactor diodes and various microwave components all of which are key elements in a parametric amplifier subsystem. Paradoxically, a number of the suppliers of such components are also engaged in the parametric amplifier field. Whether or not they will follow Microwave Associates' course and concentrate on the sale of the components rather than the end item remains to be seen.

In conclusion, the question of whether parametric amplifiers will prove to be a boom or a bust segment of the microwave industry must remain a moot point at this time. The answer should be somewhat more apparent twelve months from now. Whatever the answer, the outcome will be of both academic and real interest to the microwave industry in general. Certainly it will be a case history which the industry can speculate upon and profit from as other new products emerge in the future.

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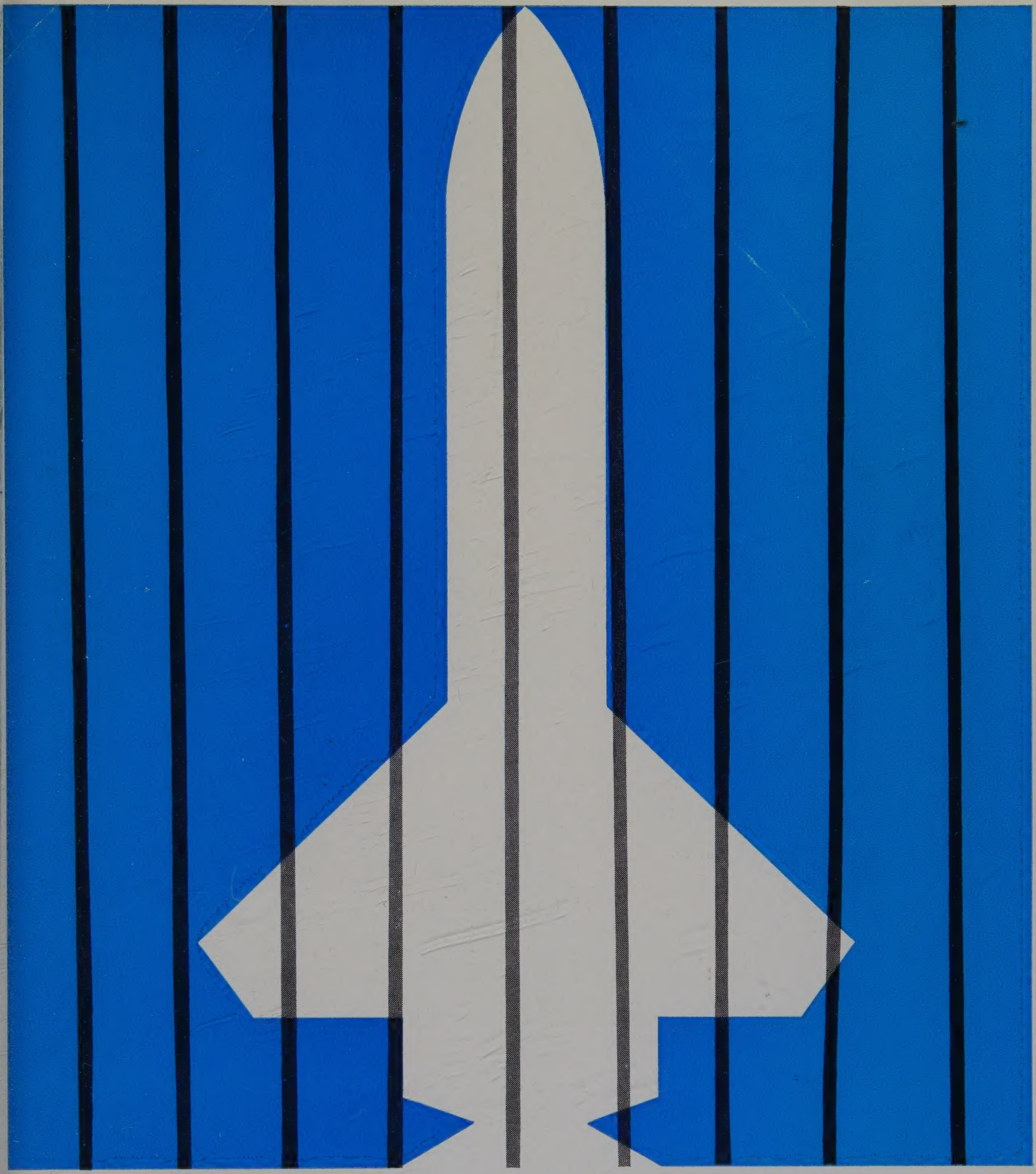

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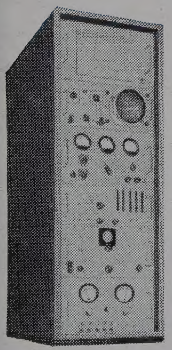

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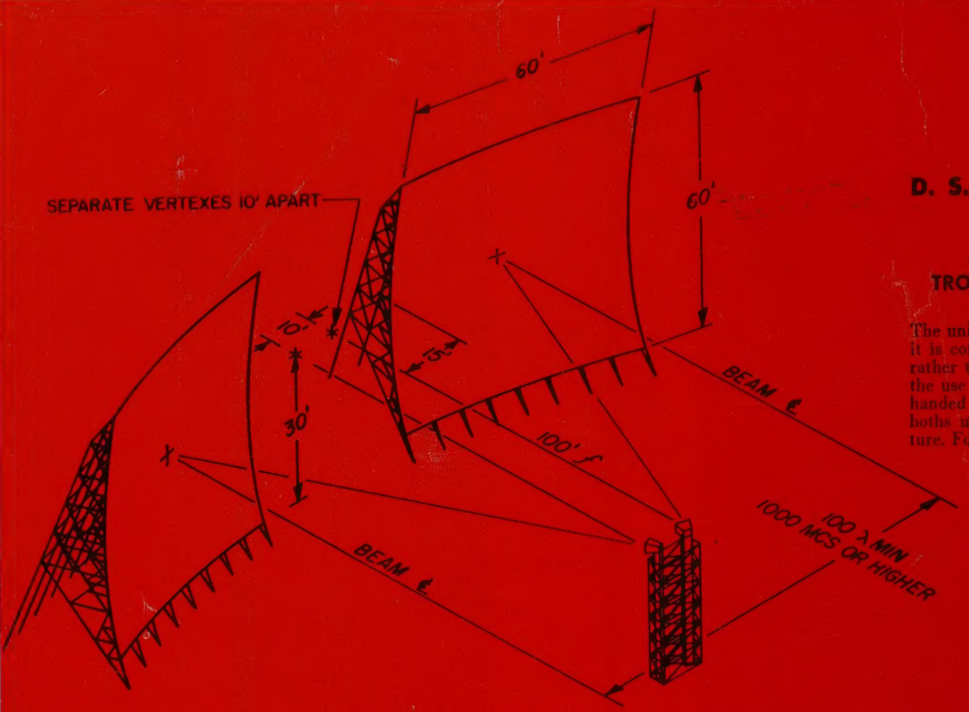

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Route 3A, Cohasset, Mass.

total integrated capability *

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many claim it . . .
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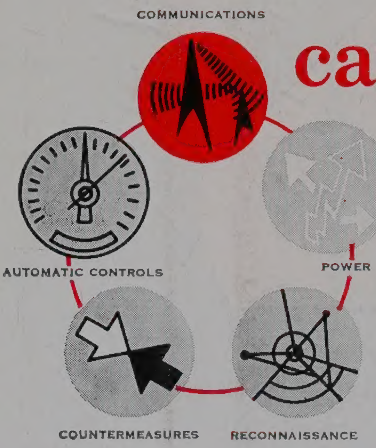

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*
Definition:
The ability to accomplish in a specific area, initial concept, design, fabrication, maintenance and management of entire projects by utilizing separate but related facilities and technically oriented talents under the coordination of one administration.

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D. S. Kennedy Division
Anchor Metals Division
Electronics Division
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Systems Laboratory Division
Relay Division
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